UNIVERSITY OF SOUTHERN CALIFORNIA

BUILDING PERIODS FOR USE IN EARTHQUAKE RESISTANT DESIGN CODES – EARTHQUAKE RESPONSE DATA COMPILATION AND ANALYSIS OF TIME AND AMPLITUDE VARIATIONS

Final Project Report

Submitted to U.S. Geological Survey External Research Program

Project No. 03HQGR0013

(12/01/2003—11/30/2004)

Principal Investigator:

Maria I. Todorovska
University of Southern California
Civil Engineering Department
Los Angeles, CA 90089-2531
Tel. (213) 740-0616; fax. (213) 744-1426
E-mail: mtodorov@usc.edu;
URL: http://www-rcf.usc.edu/~mtodorov/

Other contributors:

M. D. Trifunac
T.-Y Hao
V. Gicev

Los Angeles
February, 2004

BUILDING PERIODS FOR USE IN EARTHQUAKE RESISTANT DESIGN CODES – EARTHQUAKE RESPONSE DATA COMPILATION AND ANALYSIS OF TIME AND AMPLITUDE VARIATIONS

Final Project Report

Submitted to U.S. Geological Survey External Research Program

Project No. 03HQGR0013

(12/01/2003—11/30/2004)

Principal Investigator:
Maria I. Todorovska
University of Southern California
Civil Engineering Department
Los Angeles, CA 90089-2531
Tel. (213) 740-0616; fax. (213) 744-1426
E-mail: mtodorov@usc.edu;
URL: http://www-rcf.usc.edu/~mtodorov/

Other contributors:
M. D. Trifunac
T.-Y Hao
V. Gicev

ABSTRACT

Estimation of the frequencies of buildings from actual earthquake response data, and understanding how it varies with time and as a function of the level of shaking is very important for the improvement of the building codes, as the design base shear coefficient and the response amplitudes are estimated based on the building frequency.

This project contributed new data of the response of seven USGS buildings in the Los Angeles area to the 1994 Northridge earthquake and its aftershocks, which was digitized and processed for this project. Although the number of recorded aftershocks in many of these buildings was large (up to about 80), only a small number of records were found to be useable for analysis of the building frequencies, because of the small signal to noise ratio at long periods. These data was used to estimate the building frequency as a function of time, and find out whether and by how much it changes. Data was initially processed for 15 other buildings, for which there are "good" film records of other earthquakes that should be added to the analysis. It is planned to complete the processing of the Northridge data, digitize and process the additional film records during a second phase of this project, for which funding is hoped to be secured.

The system frequency was estimated by two methods—zero crossing analysis, and from the ridge of the Gabor transform. In general, the trend indicated by these data is decrease during the earthquakes that caused the largest levels of response (1994 Northridge main event, and the 1971 San Fernando earthquake), and "recovery" during the shaking from the aftershocks. For one of the buildings, a significant change that occurred during the San Fernando earthquake (30% reduction) appears to have been permanent. For most buildings, the frequency changed up to 20%, but for two buildings, the change was about 30%. A permanent reduction of the frequency is consistent with permanent loss of stiffness, while a "recovery" to the initial higher value is consistent with the interpretation that the change was mainly due to changes in the soil (rather than in the structure itself), or changes in the bond between the soil and the foundation. A detailed analysis of the causes of these changes is beyond the scope of this project.

TABLE OF CONTENTS

1. INTRODUCTION

The Earthquake Resistant Design Codes have evolved based on principles and procedures derived from the Response Spectrum Method. In most codes, the design shear forces are quantified using the seismic coefficient $C(T)$, where T is the "fundamental vibration period of the building," and various scaling factors that depend on the seismic zone, type of structure, soil site conditions, importance of structure etc. Most codes provide simplified empirical equations for estimation of the building period, T, based on past experience and on data of response of existing buildings, which is extremely limited (both in quantity and in quality). Significant new improvements in the code procedures, or improvement of the accuracy of the existing code equations can be made only if the processed data on recorded earthquake response is significantly expanded.

For most buildings, the design base shear and the lateral design forces are function of its fundamental period, T, via the seismic coefficient $C(T)$. As T cannot be measured before the structure is completed, the building codes provide simplified empirical equations to estimate it, based on measured response of existing buildings. Numerous papers on this subject have approached this problem theoretically (Biot, 1942), using small amplitude ambient and forced vibration tests of structures (Carder, 1936), and actual earthquake response (Li and Mau, 1979). However, the number of well-documented buildings with one or several earthquake recordings is typically less than 100. When the recorded data is grouped by the structural systems (frame, shear wall etc.) and building materials (reinforced concrete, steal, etc.), the number of records in a particular group becomes too small to control the accuracy of regression analyses, or to separate the "good" from the "bad" empirical models (Goel and Chopra, 1997; Stewart et al., 1999). This problem is further complicated by the fact that the foundation soil responds in nonlinear manner, even for very small strains (Hudson, 1970; Luco et al., 1987). During strong earthquake shaking, the apparent period, $\tilde{T}$, of the soil-foundation-structure system can lengthen significantly (Udwadia and Trifunac, 1974), and it may or may not return to its original pre earthquake value. This period lengthening can reach and exceed a factor of two, and it adds to the scatter in empirical estimation of the building periods, and to the ambiguity in choosing a representative period T for evaluation of the seismic coefficient $C(T)$. There are many complex aspects of this problem (e.g. how soil-structure interaction changes the estimates of $\tilde{T}$, and how valid and useful are the models developed so far), which must be addressed by future earthquake hazard reduction research, but analysis and resolution of those is well beyond the scope of this project. This project addresses the obvious and essential first step, that is to increase the available data on apparent building periods $\tilde{T}$ during actual earthquake excitation. Without a major increase of the database of structural response to earthquakes, little progress can be made in future developments of the building codes and of new procedures for earthquake resistant design.

Especially valuable data for estimation of amplitude dependent lengthening and recovery of $\widetilde{T}$ come from buildings with *multiple* recordings. These multiple recordings can be used to estimate empirically the dependence of system period $\widetilde{T}$ on the overall response amplitudes and on the strain levels in the soil. Unfortunately, due to limited funding and to the fact that most records in buildings are on film, only larger amplitude records in buildings are usually processed. This has left the dataset of structural records deficient in multiple recordings in buildings.

Recording strong motion in structures (and in general) is a slow process (as strong earthquake are rare events) and requires significant financial investment (in instrumentation and in long term maintenance) and long waiting time to record. Fortunately, the set of processed building response records can be significantly expanded without having to wait for tens of years to record, as there is a large amount of such data already recorded (by stations of the National and State of California Strong Motion Programs, and in many tall buildings instrumented by their owner). Records not digitized by these agencies include those of aftershocks of major earthquakes, of many smaller earthquakes, and of large but distant earthquakes. For example, in the Los Angeles metropolitan area, this includes aftershocks of the 1987 Whittier-Narrows (M=5.9), 1994 Northridge (M=6.7), many smaller earthquakes, such as 1988 Pasadena (M=4.9), 1990 Upland (M=5.2), 1991 Sierra Madre (M=5.8), and 1989 Montebello (M=4.4 and M=4.1), 1992 Landers (M=7.5), 1999 Hector Mine (M=7.1), 2001 West Hollywood (M=4.2), and other smaller earthquakes.

The objective of this one year project has been to *initiate* the augmentation of the pool of processed structural response data, in particular with *multiple* recordings corresponding to different levels of shaking, by digitizing and processing records in buildings of aftershocks of the 1994 Northridge earthquake (as well as of records of the main event not yet processed or processed inadequately), that have been archived by the U.S. Geological Survey, and demonstrate the usefulness of such recordings for estimation of the building periods and improvement of the building design codes. We do that by presenting results for the estimated building frequencies from the processed data and their variation as a function of the level of response and time, from one event to another and during a particular event. After having demonstrated the usefulness of such data, we plan to submit a proposal to continue with this effort by digitization and processing of adequate data of other events recorded in buildings in the Los Angeles area.

This report is organized as follows. Chapter 2 presents a summary of the processed data for this project , Chapter 3 presents the methodology used for estimation of instantaneous frequency from building response data, Chapter 4 presents results for the building frequencies and their variation, Chapter 5 presents a summary and conclusions, and the appendices present plots of the data released (time series of acceleration, velocity and displacement and Fourier spectra of acceleration), and tables summarizing the data for each building.

2. STRONG MOTION DATA OF 1994 NORTHRIDGE EARTHQUAKE AND AFTERSHOCKS IN SELECTED BUILDINGS IN THE LOS ANGELES AREA

Figure 2.1 shows a map of the Los Angeles metropolitan area and locations of instrumented buildings at the time of the 1994 Northridge earthquake, that have been instrumented either by the U.S. Geological Survey (USGS) and partner organizations, or by the building owner (as required by the Los Angeles and state Building Codes), and for which the data is archived by USGS. The latter are often referred to as “code” buildings. All of these building will be referred to as “USGS instrumented buildings” (as opposed to other buildings in the area that have been instrumented by the California Division of Mines and Geology, CDMG), and are identified by their USGS station number.

The sensors in these buildings are either three-component SMA-1 or multi-channel CR-1 accelerographs, both recording on film. Many of the “code” buildings (~30 buildings total) have only one instrument, at the roof. This is due to a change in the original ordinance for Los Angeles, such that at present only one instrument at the roof is required. Consequently, some building owners did not continue to maintain or repair the instrument at the base or at the intermediate floors. This unfortunate fact limits considerably the use of these records, especially for analyses of soil-structure interaction. Fortunately, the roof records (per se) can be used to determine the period of the building-foundation-soil system, and the changes of this period with the amplitudes of the building response. This is due to the fact that near the system frequencies, the relative roof motion (with respect to the base) is much larger than the (absolute) motion at the base, which implies that the roof relative motion can be approximated by its absolute motion.

Since the Northridge earthquake, the analogue instrumentation in few of the USGS instrumented buildings has been replaced by digital one, and few additional buildings have been instrumented. For some of these buildings, data of smaller local earthquakes and distant larger earthquakes has been recorded and released. The recorded level of response for these events, however, is much smaller than that for the Northridge earthquake.

Figure 2.1 also shows the epicenters of earthquakes that have been recorded in these buildings. The Northridge main event was followed by a large number of aftershocks (9 of these had M>5, and 55 had M>4). Many of these larger aftershocks, as well as smaller magnitude but closer aftershocks, were recorded in the instrumented buildings. The aftershock of March 20, 1994 (M=5.2; “aftershock 392”) was recorded by the largest number of (ground motion) stations (Todorovska et al., 1999). The Northridge sequence was recorded on multiple films, archived separately. The largest number of aftershocks known to the investigators of this project is 86—at station USGS #5455, and about 60 at several other stations. However, it turned out that the number of aftershock records useable for estimation of the first building-soil frequency was very small—up to 11, and depended not only on the amplitude of recorded motions, but also on the

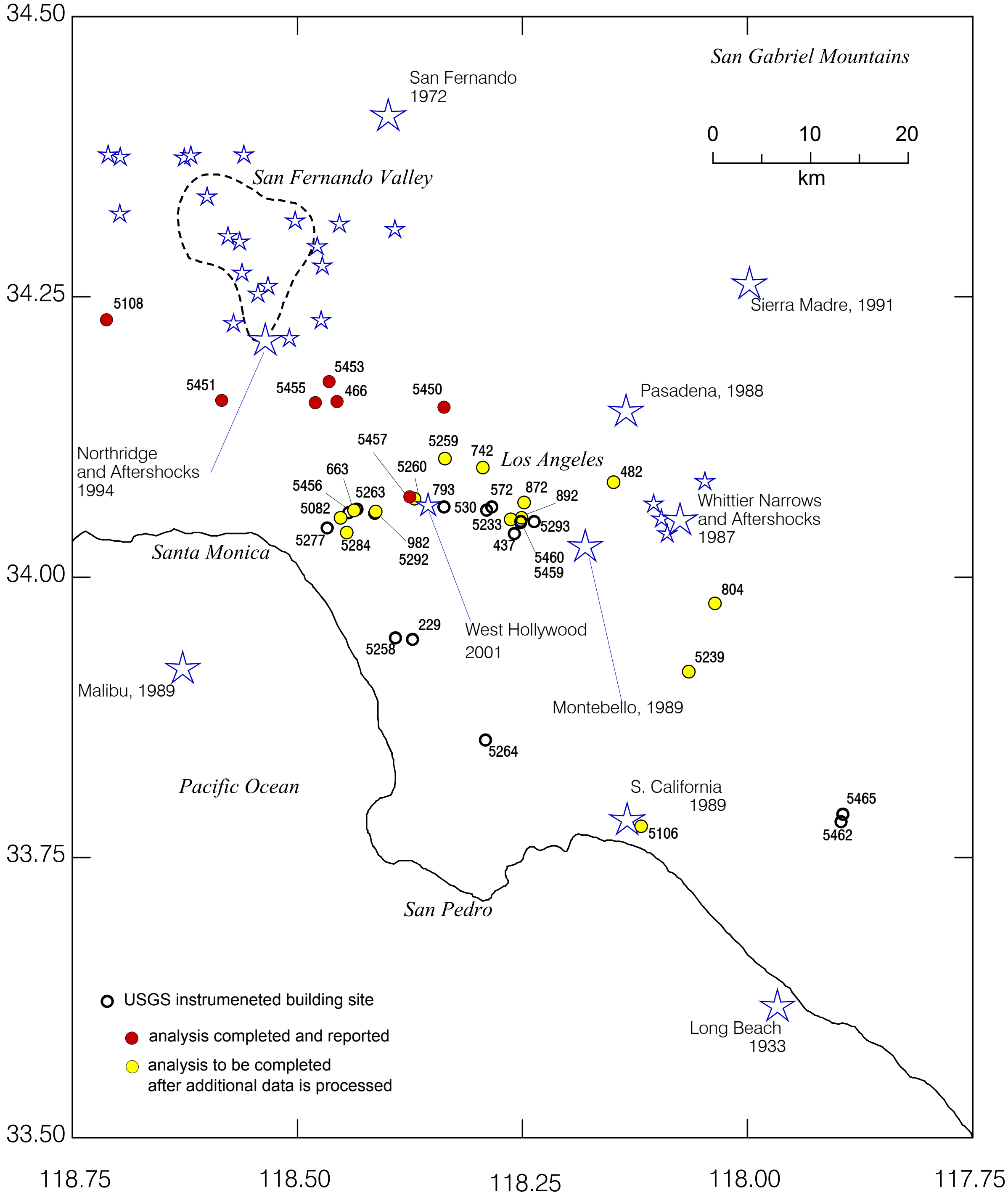


Figure 2.1 Locations of instrumented buildings in the Los Angeles metropolitan area at the time of the 1994 Northridge earthquake, for which the data is archived by USGS The building sites are identified by their USGS station number.

building itself, i.e. on its first frequency, and on the shape of the Fourier spectrum of the record relative to that of the noise. In principle, a record is useable for estimation of the building first frequency if the first frequency is within the band where the signal-to-noise ratio is grater than one, and below the Nyquist frequency. Many records turned out not to be usable because of too high low frequency cut-off, which is the frequency below which the "noise" due to the uncertainty of the baseline becomes larger than the signal, and which is determined automatically by the LeBach data processing software (Lee and Trifunac, 1990). If the first building-soil system frequency was too close to, or suspected to be below the cut-off frequency, or could not be determined reliably for some other reason, the record was discarded. An aftershock record was more likely to be useful for the buildings with smaller number of stories than for the very high buildings, which have lower first system frequency. Also, a record from a large but distant earthquake (like 1992 Landers) is more likely to be useable than a record from a small close by event with similar peak acceleration, because the ground motion from the former has more energy in the smaller frequencies of the spectrum and will excite more the first mode, leading to larger amplitudes of the building response in the smaller frequency range of the spectrum, and hence—larger signal to noise ratio at low frequencies, and lower long period cut-off frequency for the record. Therefore, it is important to have the "good" Landers earthquake records digitized and added to this analysis (photo copies of these records have been reported in USGS reports), and possible "good" Hector Mine earthquake records.

This report shows results for 7 buildings for which there were three or more adequate records (of the Northridge sequence or of the 1971 San Fernando earthquake) to estimate the first building-soil system frequency, and for which there are no other "good" records to add to the analysis, so that the analysis is considered completed. These stations are marked as full (red) dots in Figure 2.1. For the 15 stations marked by light (yellow) circles, there are some adequate records of the Northridge sequence, which have been processed initially, and for which there are other "good" records that have not yet been digitized (e.g. of the Landers and/or of the Whittier-Narrows earthquake), which should be added to the analysis. We plan to process these new data during the second phase of this project, for which we hope to secure funding from the next cycle of the USGS External Research Program. The results for these building will be presented after all data has been processed and the analysis has been completed. For the other buildings, marked in Fig. 2.1 by open circles with heavy boundaries, at this time, we do not have more than 1 or maybe two adequate records for our analysis (either because there are not such records, or because films for these buildings were not made available to us for this project). During the planned second phase of this project, we plan to process additional "good" records if there are such records and are made available to us.

Table 2.1 shows a list of earthquakes recorded or likely to have been recorded in "USGS" instrumented buildings. For the Northridge sequence, only the aftershocks are shown for which there is an adequate record that has been used in the analysis presented in this report, which has been positively identified. For most of the buildings, the contributing aftershocks have not been identified, but are associated with a *negative* aftershock number, the absolute value of which increases chronologically, and is related to the order of the record on the film (e.g., aftershock –3 means that this was the third aftershock record on the film following the main event, and aftershock –105 means that this was the fifth record on the second role of film shipped to us, which did not contain the main event). This table also lists the 2001 West Hollywood earthquake (M=4.2), which occurred very close to many of the instrumented buildings (see Figure 2.1), and which should have been recorded by these buildings.

Table 2.1 Earthquakes recorded by USGS instrumented buildings.

Event	Date	Time	M_L	Latitude	Longitude	Depth (km)
San Fernando	02/09/1971	06:00	6.6	34 24 42N	118 24 00W	--
Whittier-Narrows	10/01/1987	14:42	5.9	34 03 10N	118 04 34W	14.5
Whittier-Narrows, 12th Aft.	10/04/1987	10:59	5.3	34 04 01N	118 06 19W	13.0
Whittier-Narrows, 13th Aft.	02/03/1988	15:25	4.7	34 05 13N	118 02 52W	16.7
Pasadena	12/03/1988	11:38	4.9	34 08 56N	118 08 05W	13.3
Malibu	01/19/1989	06:53	5.0	33 55 07N	118 37 38W	11.8
Montebello	06/12/1989	16:57	4.4	34 01 39N	118 10 47W	15.6
Upland	02/28/1990	23:43	5.2	34 08 17N	117 42 10W	5.3
Sierra Madre	06/28/1991	14:43	5.8	34 15 45N	117 59 52W	12.0
Landers	06/28/1992	11:57	7.5	34 12 06N	116 26 06W	5.0
Big Bear	06/28/1992	15:05	6.5	34 12 06N	116 49 36W	5.0
Northridge	01/17/1994	12:30	6.7	34 12 48N	118 32 13W	18.4
Northridge, Aft. #1	01/17/1994	12:31	5.9	34 16 45N	118 28 25W	0.0
Northridge, Aft. #7	01/17/1994	12:39	4.9	34 15 39N	118 32 01W	14.8
Northridge, Aft. #9	01/17/1994	12:40	5.2	34 20 29N	118 36 05W	0.0
Northridge, Aft. #100	01/17/1994	17:56	4.6	34 13 39N	118 34 20W	19.2
Northridge, Aft. #129	01/17/1994	20:46	4.9	34 18 04N	118 33 55W	9.5
Northridge, Aft. #142	01/17/1994	23:33	5.6	34 19 34N	118 41 54W	9.8
Northridge, Aft. #151	01/18/1994	00:43	5.2	34 22 35N	118 41 53W	11.3
Northridge, Aft. #253	01/19/1994	21:09	5.1	34 22 43N	118 42 42W	14.4
Northridge, Aft. #254	01/19/1994	21:11	5.1	34 22 40N	118 37 10W	11.4
Northridge, Aft. #336	01/29/1994	11:20	5.1	34 18 21N	118 34 43W	1.1
Northridge, Aft. #392	03/20/1994	21:20	5.2	34 13 52N	118 28 30W	13.1
Hector Mine	10/16/1999	09:46	7.1	34 36 00N	116 16 12W	3.0
West Hollywood	09/09/2001	23:59	4.2	34 04 30N	118 22 44W	3.7

Tables 2.2 through 2.9 show a summary of the records of the Northridge sequence that were processed and found useable for this project. Each table corresponds to a pair of a station and an instrument. For all but one building (USGS 5108), there was only one instrument on the top floor or on the roof. Each table shows in the header row the USGS station number, the instrument type and serial number, station address and location of the instrument within the building, and the station geographical coordinates. The following rows show the file name containing the processed data (v1x????.dat has the uncorrected acceleration time series, v2x????.dat has the corrected acceleration, velocity and displacement time histories, and v3x????.dat has the Fourier and response spectra), the record reference and log numbers (which have no special meaning for the users), the name of the event (negative aftershock number means unidentified aftershock, as described in the previous paragraph), the epicentral distance (for the unidentified aftershocks, the horizontal distance to a central point on the fault plane is shown (as an indicator of the order of magnitude of the distance), the duration of the digitized record (all recorded length was digitized), component orientation, and uncorrected peak acceleration. Plots of the corrected acceleration, velocity and displacement time series, and of Fourier spectra of acceleration (three components per page) are shown in the appendices, named as A.???? where ???? is the USGS station number. A CD Rom is enclosed containing electronic files of these data (of uncorrected acceleration, corrected acceleration, velocity and displacement, and Fourier and response spectra).

Table 2.2 List of processed records at station USGS 0466

USGS: 0466 SMA-1 185	LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th floor)					34.157°N 117.476°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp	Peak Acc. [g]
v1x0000.dat	IAA000	94.000.0	NORTHRIDGE EARTHQUAKE	9.0	59.7	N00E UP W00N	0.550 0.394 0.257
v1x0001.dat	IAA001	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	15.9	33.2	N00E UP W00N	0.151 0.097 0.054

Table 2.3 List of processed records at station USGS 5108 – 6th floor

USGS: 5108 SMA 1276	SANTA SUSANA, ETEC Bldg 462 (6th Floor)					34.230°N 118.712°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp	Peak Acc. [g]
V1X8900.dat	IAA001	94.890.0	NORTHRIDGE EARTHQUAKE	16.3	59.8	E00S UP N00E	0.392 0.398 0.595
V1X8901.dat	IAA002	94.890.1	NORTHRIDGE EARTHQUAKE (aft. 7)	16.8	34.2	E00S UP N00E	0.019 0.018 0.019
V1X8902.dat	IAA003	94.890.2	NORTHRIDGE EARTHQUAKE (aft. 9)	16.1	43.1	E00S UP N00E	0.032 0.040 0.045
V1X8904.dat	IAA005	94.890.4	NORTHRIDGE EARTHQUAKE (aft. 100)	12.9	37.6	E00S UP N00E	0.039 0.027 0.025
V1X8905.dat	IAA006	94.890.5	NORTHRIDGE EARTHQUAKE (aft. 129)	15.7	42.8	E00S UP N00E	0.165 0.106 0.127
V1X8906.dat	IAA007	94.890.6	NORTHRIDGE EARTHQUAKE (aft. 142)	10.9	46.0	E00S UP N00E	0.129 0.071 0.075
V1X8907.dat	IAA008	94.890.7	NORTHRIDGE EARTHQUAKE (aft. 151)	16.4	34.9	E00S UP N00E	0.021 0.017 0.035
V1X8908.dat	IAA009	94.890.8	NORTHRIDGE EARTHQUAKE (aft. 253)	16.5	43.1	E00S UP N00E	0.089 0.051 0.046
V1X8909.dat	IAA010	94.890.9	NORTHRIDGE EARTHQUAKE (aft. 254)	18.5	43.9	E00S UP N00E	0.034 0.031 0.025
V1X8910.dat	IAA011	94.891.0	NORTHRIDGE EARTHQUAKE (aft. 336)	14.9	42.7	E00S UP N00E	0.089 0.074 0.070
V1X8911.dat	IAA012	94.891.1	NORTHRIDGE EARTHQUAKE (aft. 392)	16.5	41.8	E00S UP N00E	0.043 0.037 0.038

Table 2.4 List of processed records at station USGS 5108 – 1st floor

USGS: 5108 SMA 1277	SANTA SUSANA, ETEC Bldg 462 (1st Floor)					34.230°N 118.712°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp	Peak Acc. [g]
V1X0300.dat	IAA013	94.030.0	NORTHRIDGE EARTHQUAKE	16.3	60.1	E00S UP N00E	0.236 0.226 0.335
V1X0301.dat	IAA014	94.030.1	NORTHRIDGE EARTHQUAKE (aft. 7)	16.8	34.2	E00S UP N00E	0.023 0.010 0.022
V1X0302.dat	IAA015	94.030.2	NORTHRIDGE EARTHQUAKE (aft. 9)	16.1	43.1	E00S UP N00E	0.037 0.019 0.032
V1X0304.dat	IAA018	94.030.4	NORTHRIDGE EARTHQUAKE (aft. 100)	12.9	37.6	E00S UP N00E	0.030 0.015 0.023
V1X0305.dat	IAA019	94.030.5	NORTHRIDGE EARTHQUAKE (aft. 129)	15.7	42.8	E00S UP N00E	0.151 0.045 0.181
V1X0306.dat	IAA020	94.030.6	NORTHRIDGE EARTHQUAKE (aft. 142)	10.9	46.5	E00S UP N00E	0.043 0.047 0.061
V1X0307.dat	IAA021	94.030.7	NORTHRIDGE EARTHQUAKE (aft. 151)	16.4	31.8	E00S UP N00E	0.016 0.010 0.024
V1X0308.dat	IAA022	94.030.8	NORTHRIDGE EARTHQUAKE (aft. 253)	16.5	43.1	E00S UP N00E	0.036 0.024 0.039
V1X0309.dat	IAA023	94.030.9	NORTHRIDGE EARTHQUAKE (aft. 254)	18.5	43.9	E00S UP N00E	0.027 0.016 0.021
V1X0310.dat	IAA024	94.031.0	NORTHRIDGE EARTHQUAKE (aft. 336)	14.9	42.7	E00S UP N00E	0.096 0.036 0.090
V1X0311.dat	IAA025	94.031.1	NORTHRIDGE EARTHQUAKE (aft. 392)	16.5	41.8	E00S UP N00E	0.047 0.021 0.047

Table 2.5 List of processed records at station USGS 5450

USGS: 5450 SMA-1 6146	BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)					34.152°N 118.337°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp	Peak Acc. [g]
v1x0000.dat	IAA000	94.000.0	NORTHRIDGE EARTHQUAKE	19.6	47.4	N00E UP W00N	0.644 1.060 0.508
v1x0001.dat	IAA001	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	21.4	21.9	N00E UP W00N	0.069 0.065 0.085
v1x0005.dat	IAA005	94.000.5	NORTHRIDGE EARTHQUAKE (aft. -5)	21.4	16.3	N00E UP W00N	0.024 0.031 0.027
v1x0013.dat	IAA013	94.001.3	NORTHRIDGE EARTHQUAKE (aft. -13)	21.4	21.8	N00E UP W00N	0.036 0.041 0.031
v1x0014.dat	IAA014	94.001.4	NORTHRIDGE EARTHQUAKE (aft. -14)	21.4	11.6	N00E UP W00N	0.020 0.014 0.011

Table 2.6 List of processed records at station USGS 5451

USGS: 5451 SMA-1 4048	LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)					34.185°N 118.584°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp	Peak Acc. [g]
v1x0000.dat	IAA000	94.000.0	NORTHRIDGE EARTHQUAKE	5.4	99.2	N00E UP W00N	0.552 0.477 0.373
v1x0026.dat	IAA026	94.002.6	NORTHRIDGE EARTHQUAKE (aft. -26)	15.55	41.5	N00E UP W00N	0.077 0.068 0.073
v1x0115.dat	IAA115	94.011.5	NORTHRIDGE EARTHQUAKE (aft. -115)	15.55	38.3	N00E UP W00N	0.034 0.090 0.045

Table 2.7 List of processed records at station USGS 5453

USGS: 5453 SMA-1 7073	LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)					34.175°N 118.465°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp	Peak Acc. [g]
v1X0000.DAT	IAA034	94.000.0	NORTHRIDGE EARTHQUAKE	7.9	60.9	N00E	0.735
						UP	0.488
						W00N	0.663
v1X0001.DAT	IAA034	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	14.0	30.6	N00E	0.231
						UP	0.104
						W00N	0.130
v1X0007.DAT	IAA034	94.000.7	NORTHRIDGE EARTHQUAKE (aft. -7)	14.0	18.1	N00E	0.026
						UP	0.015
						W00N	0.023
v1X0024.DAT	IAA034	94.002.4	NORTHRIDGE EARTHQUAKE (aft. -24)	14.0	21.1	N00E	0.040
						UP	0.021
						W00N	0.053
v1X0026.DAT	IAA034	94.002.6	NORTHRIDGE EARTHQUAKE (aft. -26)	14.0	23.2	N00E	0.057
						UP	0.047
						W00N	0.086
v1X0029.DAT	IAA034	94.002.9	NORTHRIDGE EARTHQUAKE (aft. -29)	14.0	23.2	N00E	0.041
						UP	0.017
						W00N	0.044
v1X0103.DAT	IAA103	94.010.3	NORTHRIDGE EARTHQUAKE (aft. -103)	14.0	24.5	N00E	0.045
						UP	0.017
						W00N	0.037
v1X0104.DAT	IAA104	94.010.4	NORTHRIDGE EARTHQUAKE (aft. -104)	14.0	19.1	N00E	0.017
						UP	0.015
						W00N	0.031
v1X0115.DAT	IAA115	94.011.5	NORTHRIDGE EARTHQUAKE (aft. -115)	14.0	26.9	N00E	0.055
						UP	0.019
						W00N	0.065

Table 2.8 List of processed records at station USGS 5455

USGS: 5455 SMA-1 4270	LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)					34.156°N 118.480°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp	Peak Acc. [g]
v1x0000.dat	IAA000	94.000.0	NORTHRIDGE EARTHQUAKE	8.2	57.6	E30S	0.358
						UP	0.337
						N30E	0.394
v1x0001.dat	IAA001	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	15.9	28.2	E30S	0.070
						UP	0.087
						N30E	0.104
v1x0007.dat	IAA007	94.000.7	NORTHRIDGE EARTHQUAKE (aft. -7)	15.9	23.1	E30S	0.018
						UP	0.033
						N30E	0.016
v1x0022.dat	IAA022	94.002.2	NORTHRIDGE EARTHQUAKE (aft. -22)	15.9	20.9	E30S	0.033
						UP	0.072
						N30E	0.029
v1x0025.dat	IAA025	94.002.5	NORTHRIDGE EARTHQUAKE (aft. -25)	15.9	34.7	E30S	0.043
						UP	0.056
						N30E	0.057
v1x0046.dat	IAA046	94.004.6	NORTHRIDGE EARTHQUAKE (aft. -46)	15.9	19.2	E30S	0.029
						UP	0.045
						N30E	0.041

Table 2.9 List of processed records at station USGS 5457

USGS: 5457 SMA 5491	LOS ANGELES, 8436 WEST 3rd ST., Roof (10th floor)					34.072°N 118.375°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp	Peak Acc. [g]
v1x0000.dat	IAA030	94.000.0	NORTHRIDGE EARTHQUAKE	21.7	53.2	N00E UP S90W	0.658 0.253 0.547
v1x0001.dat	IAA030	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	27.4	28.1	N00E UP S90W	0.102 0.093 0.262
v1x0004.dat	IAA030	94.000.4	NORTHRIDGE EARTHQUAKE (aft. -4)	27.4	20.3	N00E UP S90W	0.014 0.022 0.017
v1x0008.dat	IAA030	94.000.8	NORTHRIDGE EARTHQUAKE (aft. -8)	27.4	22.5	N00E UP S90W	0.031 0.023 0.057
v1x0009.dat	IAA030	94.000.9	NORTHRIDGE EARTHQUAKE (aft. -9)	27.4	27.5	N00E UP S90W	0.053 0.032 0.053
v1x0010.dat	IAA030	94.001.0	NORTHRIDGE EARTHQUAKE (aft. -10)	27.4	18.7	N00E UP S90W	0.018 0.015 0.014
v1x0013.dat	IAA030	94.001.3	NORTHRIDGE EARTHQUAKE (aft. -13)	27.4	21.6	N00E UP S90W	0.027 0.014 0.032
v1x0017.dat	IAA030	94.001.7	NORTHRIDGE EARTHQUAKE (aft. -17)	27.4	20.5	N00E UP S90W	0.018 0.014 0.021
v1x0019.dat	IAA030	94.001.9	NORTHRIDGE EARTHQUAKE (aft. -19)	27.4	30.9	N00E UP S90W	0.100 0.124 0.185

3. ESTIMATION OF INSTANTANEOUS FREQUENCY

3.1 Methodology

The instantaneous frequency was estimated by two methods: (a) zero-crossing analysis, and (b) from the ridge of the Gabor transform, both applied to the relative roof displacement, when there was a record at the base, or to the absolute displacement when only the roof response was recorded, considered as a good approximation of the relative displacement in the neighborhood of the first system frequency. Both methods were applied to the filtered displacement, such that contained only motion in the neighborhood of the first system frequency, and resembled a chirp signal. The zero-crossing analysis consists of measuring the time between consecutive zero crossings of the displacement, and assuming this time interval to be a half of the system period (see Trifunac et al., 2001a, 2001b, 2001c). The Gabor transform is a time-frequency distribution, and, up to a phase shift, it is identical to a moving window analysis with a Gaussian window in time. The instantaneous frequency was determined from the ridge of the transform, and the corresponding amplitude was estimated from the skeleton of the transform, which is the value of the transform along the ridge (see Todorovska, 2001). The wavelet transform with the complex Morlet wavelet was initially considered, which is essentially a Gabor transform with a window which varies depending on the frequency, so that it always contains same number of wavelengths. The results by both methods were found to be very similar, and no advantage was seen in using a variable window because the changes of the building frequency are relatively small, much smaller than an order of magnitude. Using constant window was convenient in the estimation of the resolution of the method. The Gabor transform was used with spread $\sigma = 1.5$. Figure 3.1.1 shows the Gabor wavelet and its Fourier transform.

3.2 Illustrations

The methodology for estimation of the instantaneous frequency of building-soil systems is illustrated by results for five records, either of the 1971 San Fernando or of the 1994 Northridge earthquakes, in the seven buildings for which results of the variation of the instantaneous frequency during multiple events are presented in compact form in Chapter 4. Figure 3.2.1 shows results for component N11E of the record of the 1971 San Fernando earthquake at station USGS 466 (Los Angeles, 15250 Ventura Blvd.), Figure 3.2.2—for component N00E of the record of the 1994 Northridge earthquake at station USGS 5450 (Burbank, 3601 West Olive Ave.), Figure 3.2.3—for component W00N of the record of the 1994 Northridge earthquake at station USGS 5451 (Los Angeles, 6301 Owensmouth Ave.), Figure 3.2.4—for component N00E of the record of the 1994 Northridge earthquake at station USGS 5453 (Los Angeles, 5805 Sepulveda Blvd.), and Figure 3.2.5—for component E30S of the record of the 1994 Northridge earthquake at station USGS 5455 (Los Angeles, 1600 Ventura Blvd.). Each of these figures shows three plots. The plot on the left hand side shows the Fourier spectrum of the relative roof displacement (solid line), or its approximation by the absolute displacement when only a roof record was available, the Fourier spectrum of acceleration at the ground floor (dashed line) if available, and a smooth approximation of the relative (or absolute) roof displacement spectrum by the marginal Gabor transform distribution (the read line). The plot on the right hand side-top shows the time history of the roof relative (or absolute) displacement (solid line), and of the ground floor displacement (dashed line) if available, for the "broad-band" data, which is the output of the standard data processing. The plot on the right hand side-middle shows the same time histories but for the "narrow-band" data, which is the broad-band data filtered so that it contains only the components in the neighborhood of the first building-soil system frequency. The cut-off and role-off frequencies, in Hz, of the Ormsby filters used are shown in the upper right corner of these plots. The plot on the right hand side-bottom shows the instantaneous frequency versus time estimated by the zero-crossing method (open circles), and from the ridge of the Gabor transform (with $\sigma = 1.5$ for all the records). The shaded rectangle in this plot has width $2\sigma_t$ and height $2\sigma_\omega$ and is a measure of the resolution of the Gabor transform method. The Gabor transform at a point (t, f) in the time frequency plane is the weighed average of the components of the function (effectively) within such a rectangle centered at that point. The method cannot resolve frequencies that are closer than σ_ω, and estimates in time that are closer than σ_t. The resolution in frequency can be increased only if the resolution in time is decreased (by increasing the time window of the Gabor wavelet, and consequently—σ_t, and vice versa.

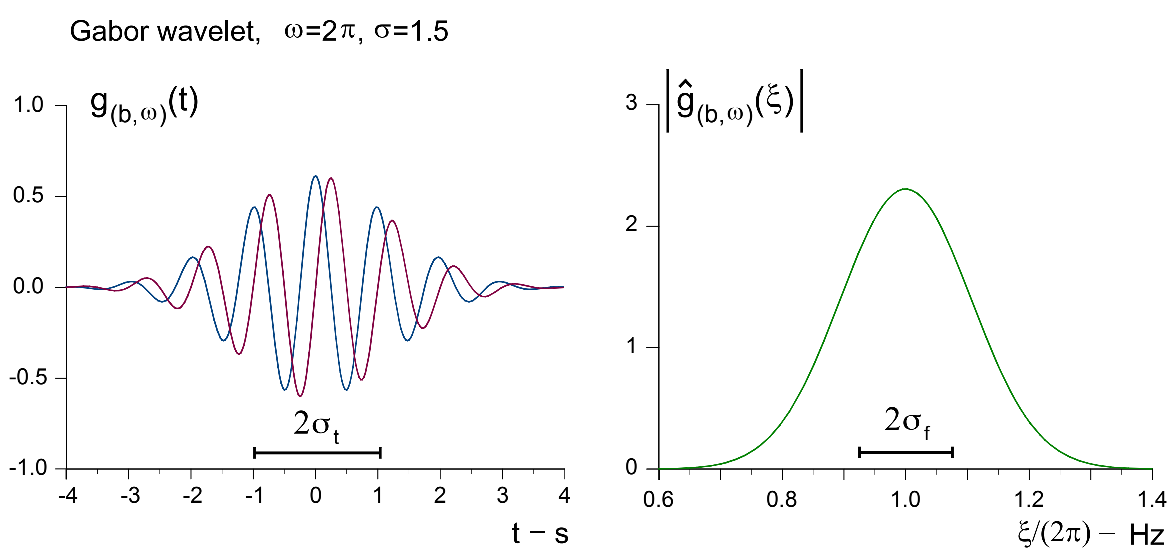


Figure 3.1.1 A Gabor wavelet for b=1 and ω=2π, in the time domain (left) and in the frequency domain (right).

The results in Figures 3.2.1 through 3.2.5 show that the estimates by the zero-crossing and from the ridge of the Gabor transform are consistent. The estimates by the latter method are smoother, as the Gabor transform is a smoothing operator. The zero-crossing method is not accurate when the oscillations of the signal depart too much from a “pure” harmonic, and these estimates are not shown. Both methods are most accurate when the amplitude of the signal is large and does not vary significantly during one cycle of oscillation, least accurate when the amplitude is small and varies significantly during one cycle, and are arbitrary when the amplitude is practically zero. Figures 3.2.1 and 3.2.4 show a significant change (decrease) in the system frequency for these buildings during a single earthquake, of about 30%, Figure 3.2.2 indicates a change of about 17%, while Fig. 3.2.5 shows no significant change. It is interesting to see whether the changes of frequency (especially where these changes are significant, even in the regions where the methods are most accurate) are permanent (indicating possible damage), or temporary (possibly due to changes in the soil, changes in the bonding condition along the contact surface between the foundation and the soil, e.g. formation of gaps between the foundation and the soil, foundation partial uplift, etc.). The answer to this important question can be obtained from analysis of records from consequent earthquakes, the results of which are shown in Chapter 4.

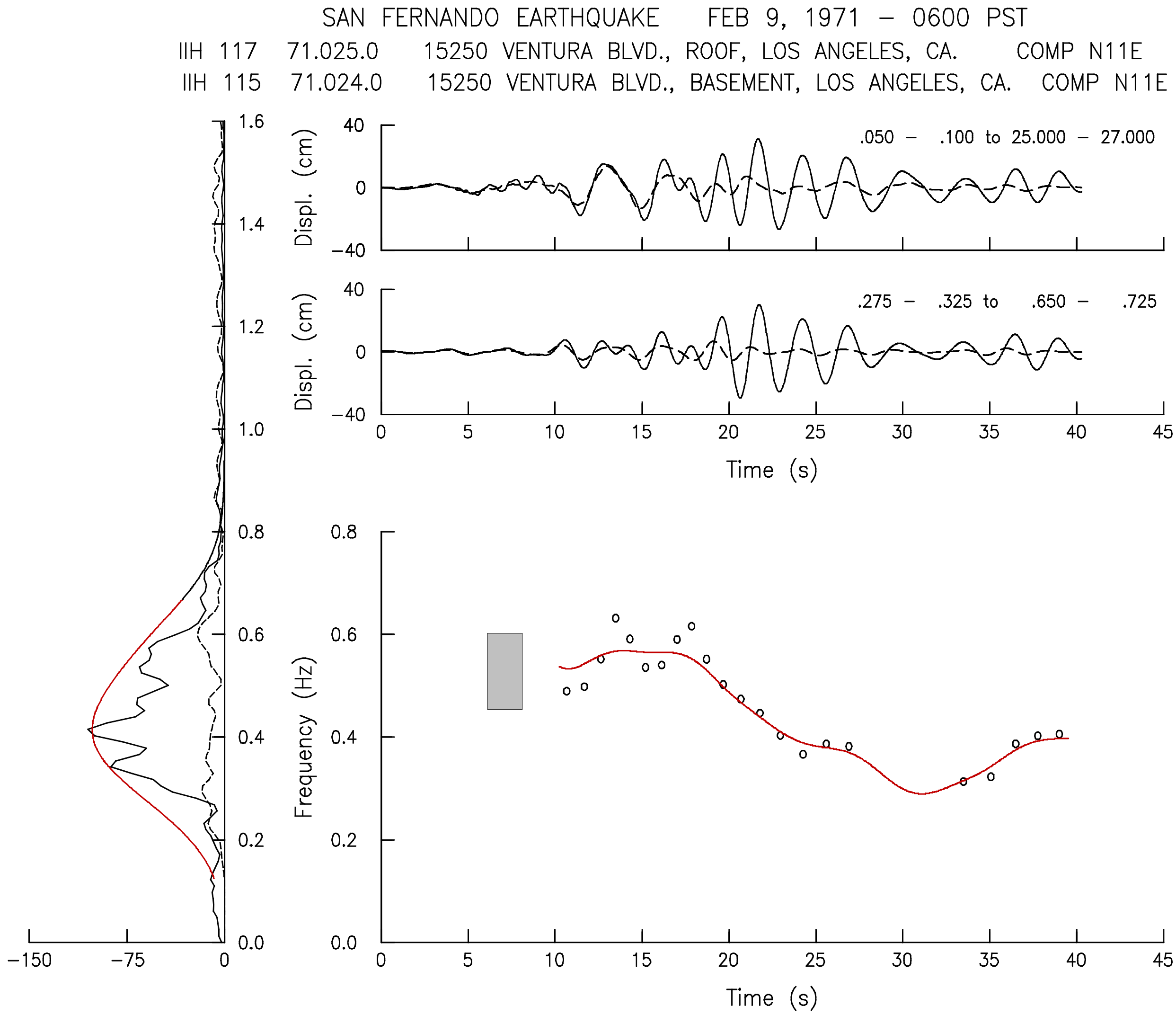


Figure 3.2.1 Estimation of the instantaneous frequency for component N11E of the record of the 1971 San Fernando earthquake at station USGS 466 (Los Angeles, 15250 Ventura Blvd.). Left: Fourier spectrum of the relative roof displacement (solid line), of acceleration at the ground floor (dashed line), and a smooth approximation of the relative roof displacement spectrum by the marginal Gabor transform distribution (the read line). Time history of the roof relative displacement (solid line), and of the ground floor displacement (dashed line), for the "broad-band" data (right-top), and for the filtered data (right-middle). Right-bottom: instantaneous frequency versus time estimated by the zero-crossing method (open circles), and from the ridge of the Gabor transform (with $\sigma = 1.5$). The shaded rectangle has width $2\sigma_t$ and height $2\sigma_\omega$, and is a measure of the resolution of the Gabor transform method.

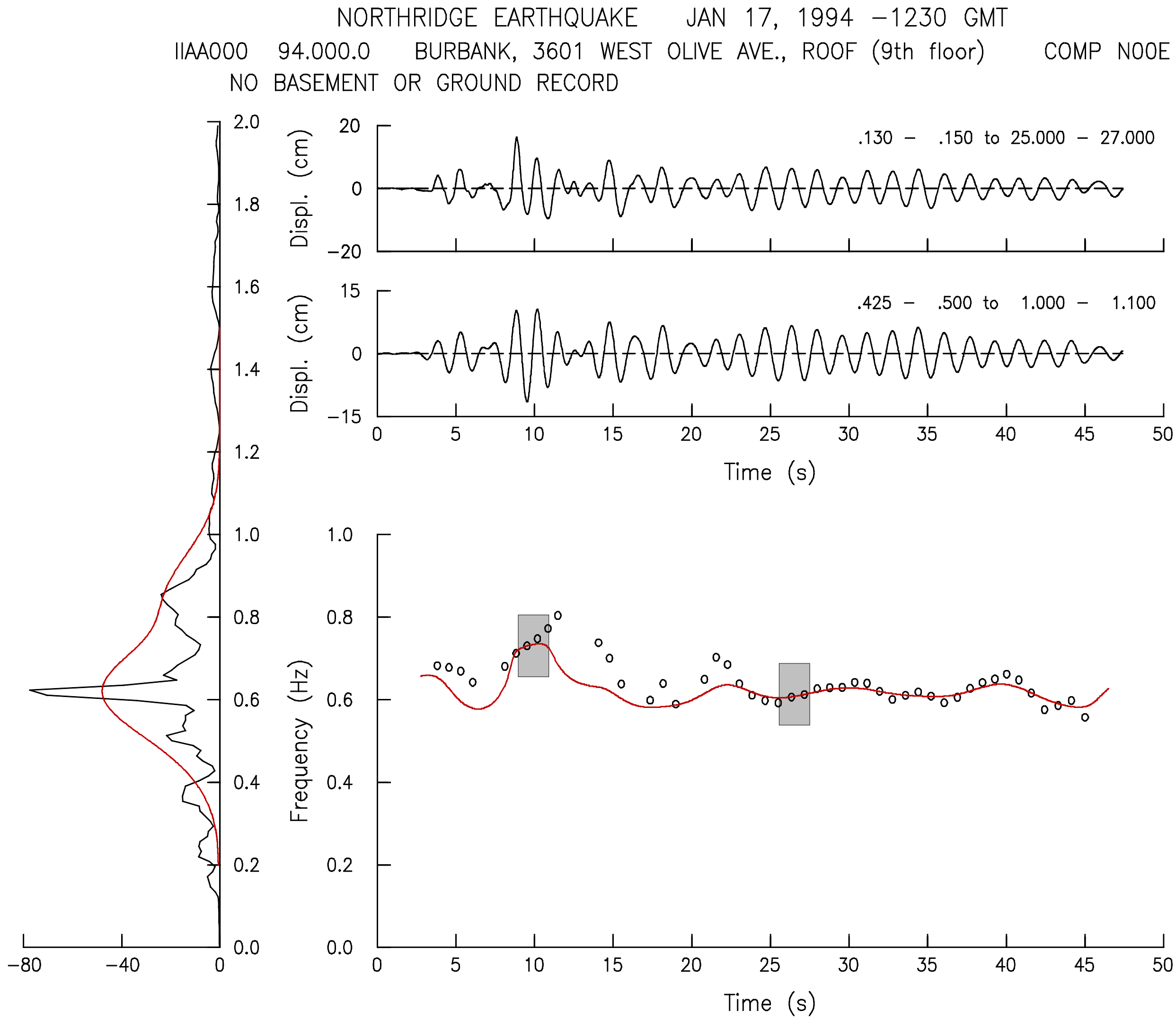


Figure 3.2.2 Estimation of the instantaneous frequency for component N00E of the record of the 1994 Northridge earthquake at station USGS 5450 (Burbank, 3601 West Olive Ave.). Left: Fourier spectrum of the relative roof displacement (solid line), and its smooth approximation by the marginal Gabor transform distribution (the read line). Time history of the roof displacement (solid line0, for the "broad-band" data (right-top), and for the filtered data (right-middle). Right-bottom: instantaneous frequency versus time estimated by the zero-crossing method (open circles), and from the ridge of the Gabor transform (with $\sigma = 1.5$). The shaded rectangle has width $2\sigma_t$ and height $2\sigma_\omega$, and is a measure of the resolution of the Gabor transform method.

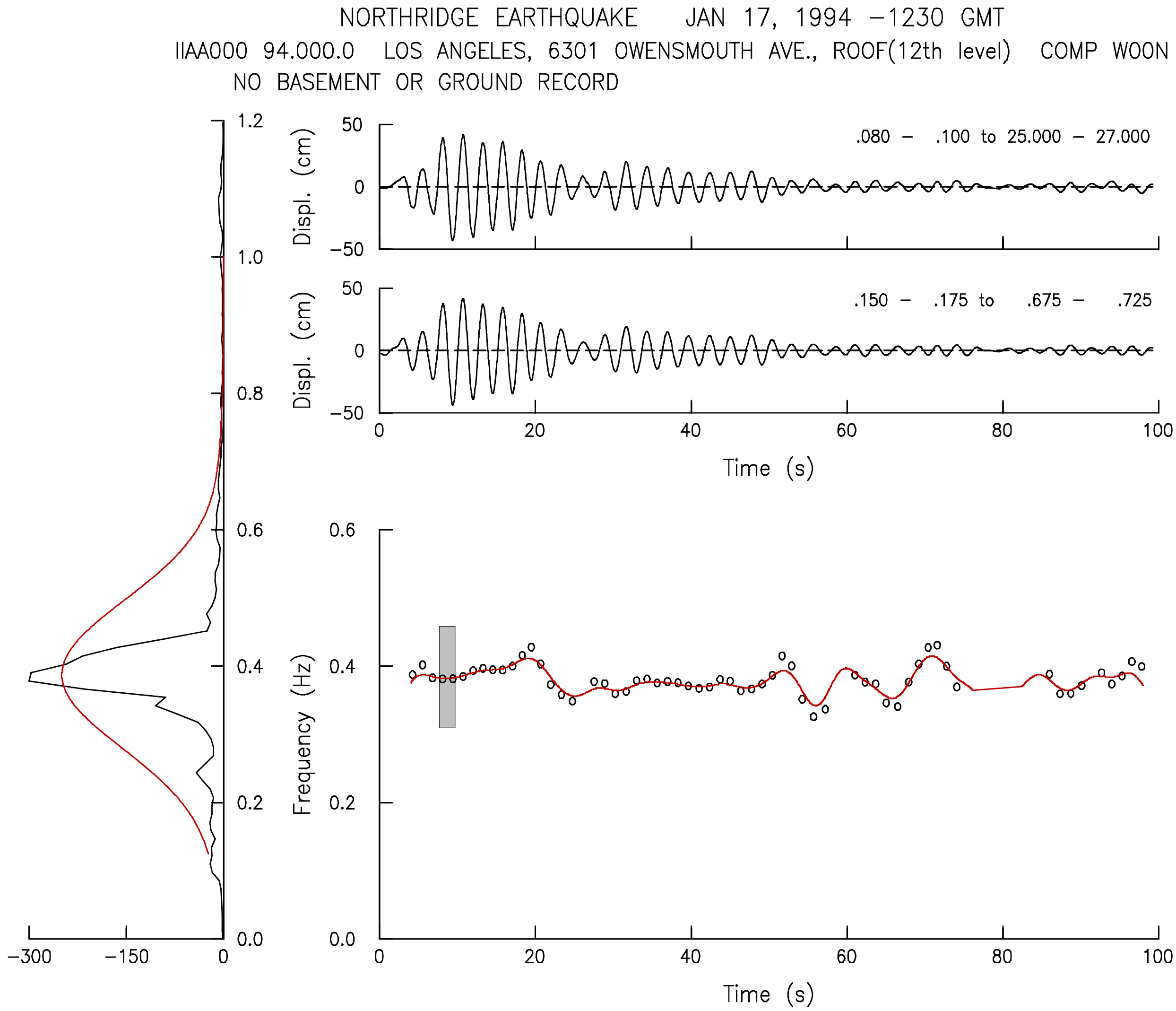


Figure 3.2.3 Estimation of the instantaneous frequency for component W00N of the record of the 1994 Northridge earthquake at station USGS 5451 (Los Angeles, 6301 Owensmouth Ave.). Left: Fourier spectrum of the relative roof displacement (solid line), and its smooth approximation by the marginal Gabor transform distribution (the read line). Time history of the roof displacement (solid line0, for the "broad-band" data (right-top), and for the filtered data (right-middle). Right-bottom: instantaneous frequency versus time estimated by the zero-crossing method (open circles), and from the ridge of the Gabor transform (with $\sigma = 1.5$). The shaded rectangle has width $2\sigma_t$ and height $2\sigma_\omega$, and is a measure of the resolution of the Gabor transform method.

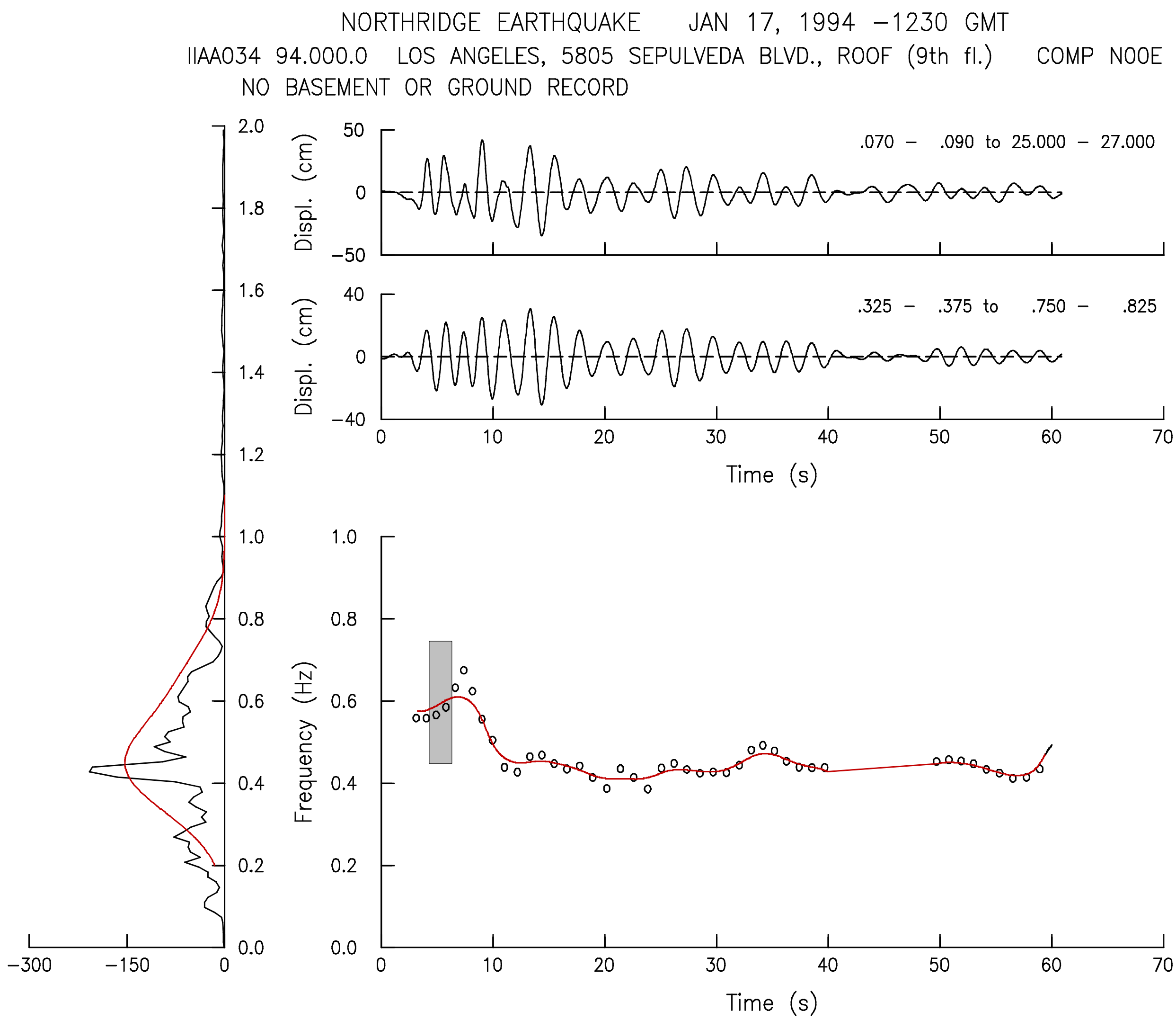


Figure 3.2.4 Estimation of the instantaneous frequency for component N00E of the record of the 1994 Northridge earthquake at station USGS 5453 (Los Angeles, 5805 Sepulveda Blvd.). Left: Fourier spectrum of the relative roof displacement (solid line), and its smooth approximation by the marginal Gabor transform distribution (the read line). Time history of the roof displacement (solid line0, for the "broad-band" data (right-top), and for the filtered data (right-middle). Right-bottom: instantaneous frequency versus time estimated by the zero-crossing method (open circles), and from the ridge of the Gabor transform (with $\sigma = 1.5$). The shaded rectangle has width $2\sigma_t$ and height $2\sigma_\omega$, and is a measure of the resolution of the Gabor transform method.

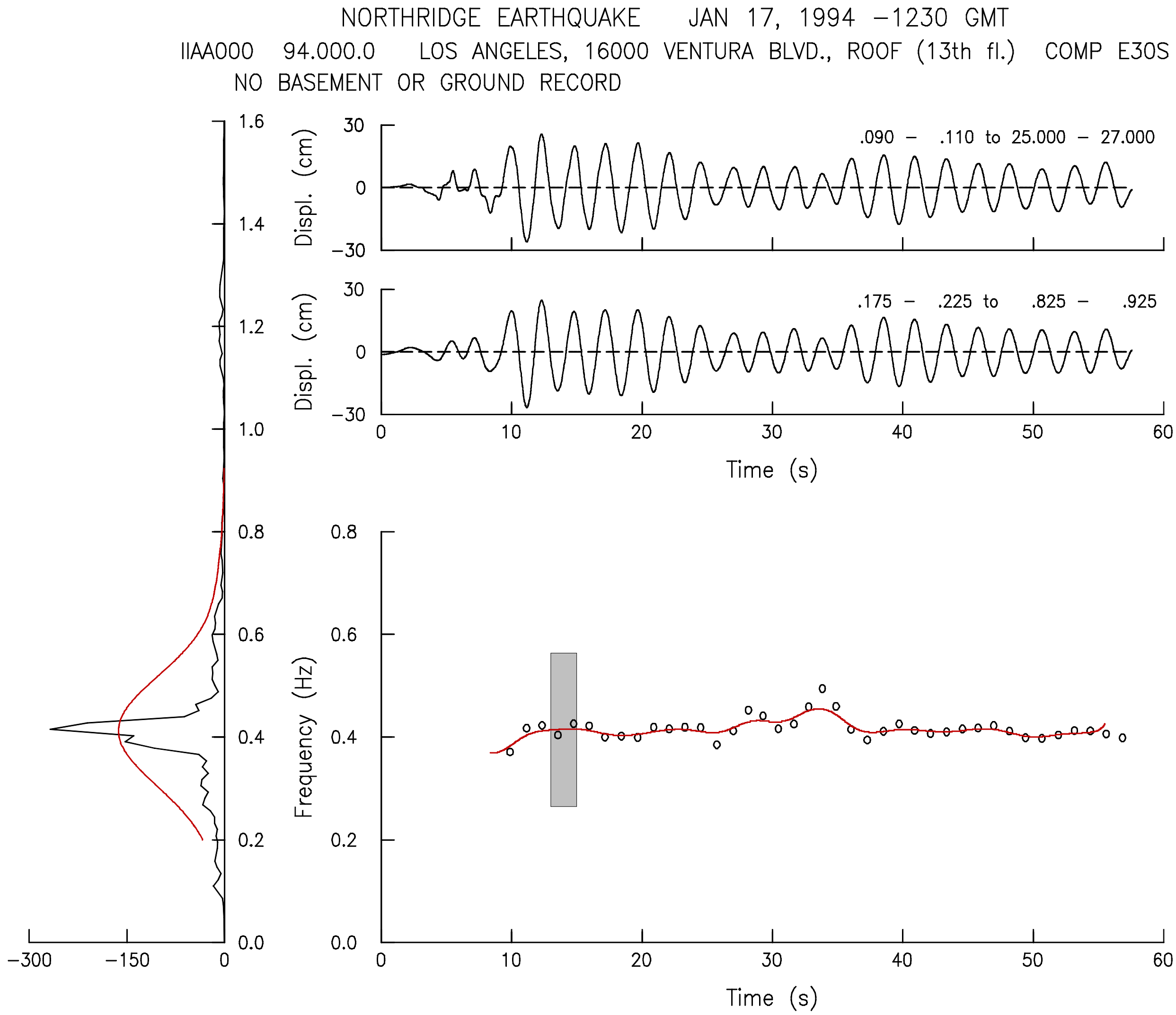


Figure 3.2.5 Estimation of the instantaneous frequency for component E30S of the record of the 1994 Northridge earthquake at station USGS 5455 (Los Angeles, 1600 Ventura Blvd.). Left: Fourier spectrum of the relative roof displacement (solid line), and its smooth approximation by the marginal Gabor transform distribution (the read line). Time history of the roof displacement (solid line0, for the "broad-band" data (right-top), and for the filtered data (right-middle). Right-bottom: instantaneous frequency versus time estimated by the zero-crossing method (open circles), and from the ridge of the Gabor transform (with $\sigma = 1.5$). The shaded rectangle has width $2\sigma_t$ and height $2\sigma_\omega$, and is a measure of the resolution of the Gabor transform method.

4. TIME AND AMPITUDE VARIATIONS OF THE INSTANTANEOUS BUILDING-SOIL SYSTEM FREQUENCY FOR SEVEN BUILDINGS

This chapter presents in a compact form results for the variation of the building-soil system frequency in time as function of the amplitude of response for seven buildings. The results are shown in Figures 4.1 through 4.28, which represent seven groups of four figures, each group corresponding to a particular building. The four figures in a group correspond to estimates of the instantaneous system frequency determined by the zero-crossing and by the Gabor transform methods, for each of the two horizontal components of motion. In each plot, the horizontal axis corresponds to the instantaneous frequency, the vertical axis corresponds to the amplitude of response (of the filtered signal) expressed in terms of the rocking angle, in radians, and each point corresponds to a particular instant in time. The points corresponding to consecutive instants of time are connected by a line. Each line corresponds to a particular earthquake. In the plots showing results for the zero-crossing method, the first and last point shown for a particular earthquake are marked respectively by an open and a closed circle.

The backbone curve, drawn by hand, indicates roughly the trend of the variation of the system frequency as function of the amplitude of response. The maximum and minimum frequencies determined from the backbone curves, and the corresponding maximum and minimum levels of response, are summarized in Table 4.1, and the percentage change for all the seven buildings is shown in Fig. 4.25. It is seen that the change for most of the buildings is not more than 20%, but it reaches 30% for two of the buildings.

From the plots in Figures 4.1 through 4.28, it can be seen that for the largest motions (during the 1971 San Fernando and 1994 Northridge earthquakes), the system frequency generally decreased during the cause of the shaking. For all but one building, this change seems to have been temporary, as the system frequency increased during the shaking from the aftershocks. For one building, permanent change appears to have occurred during the 1971 San Fernando earthquake (USGS 466). Detailed interpretation of the causes of these changes is beyond the scope of this project.

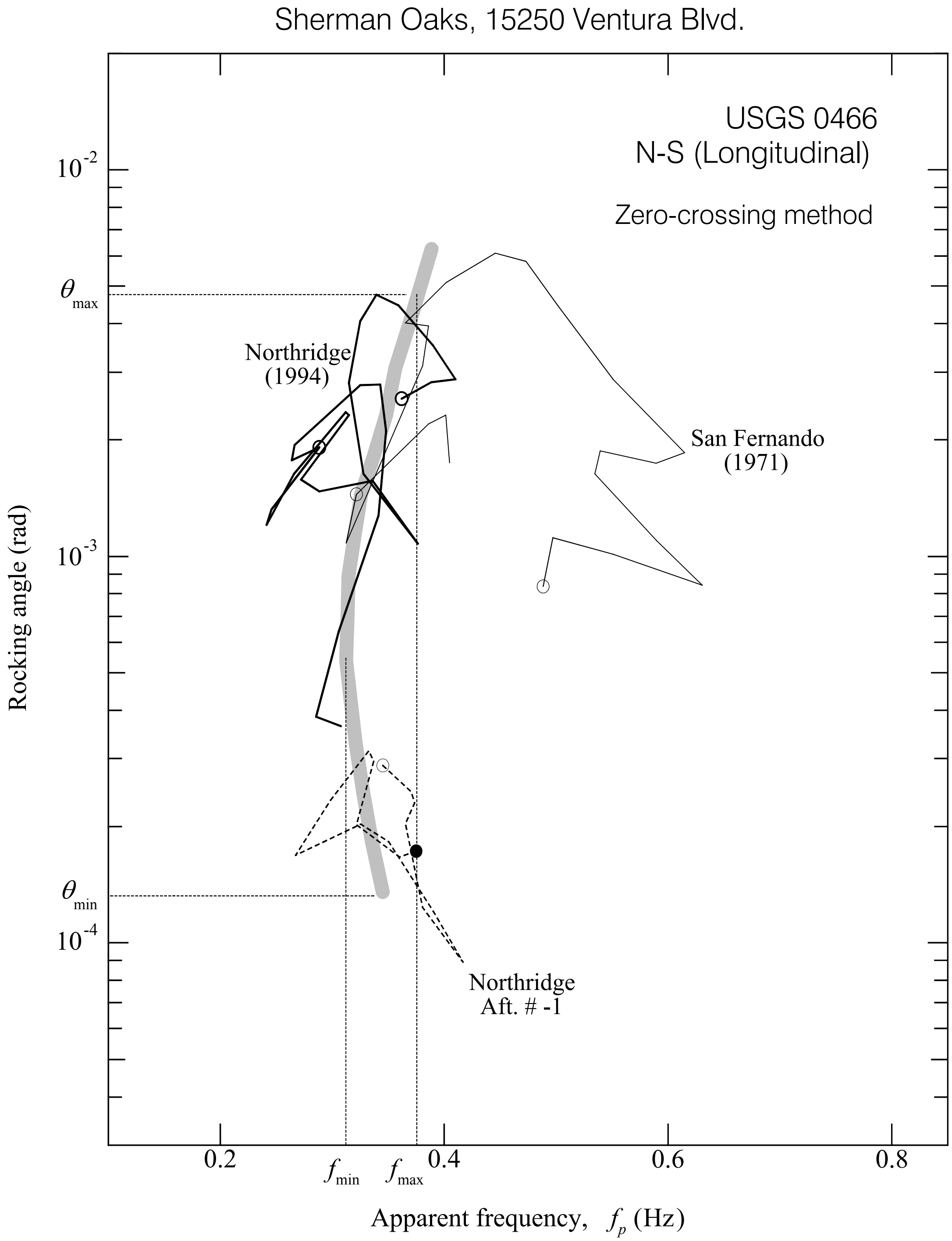


Figure 4.1 Instantaneous frequency versus amplitude of motion for station USGS 466, for N-S vibrations, determined by the zero-crossing method, for several earthquakes.

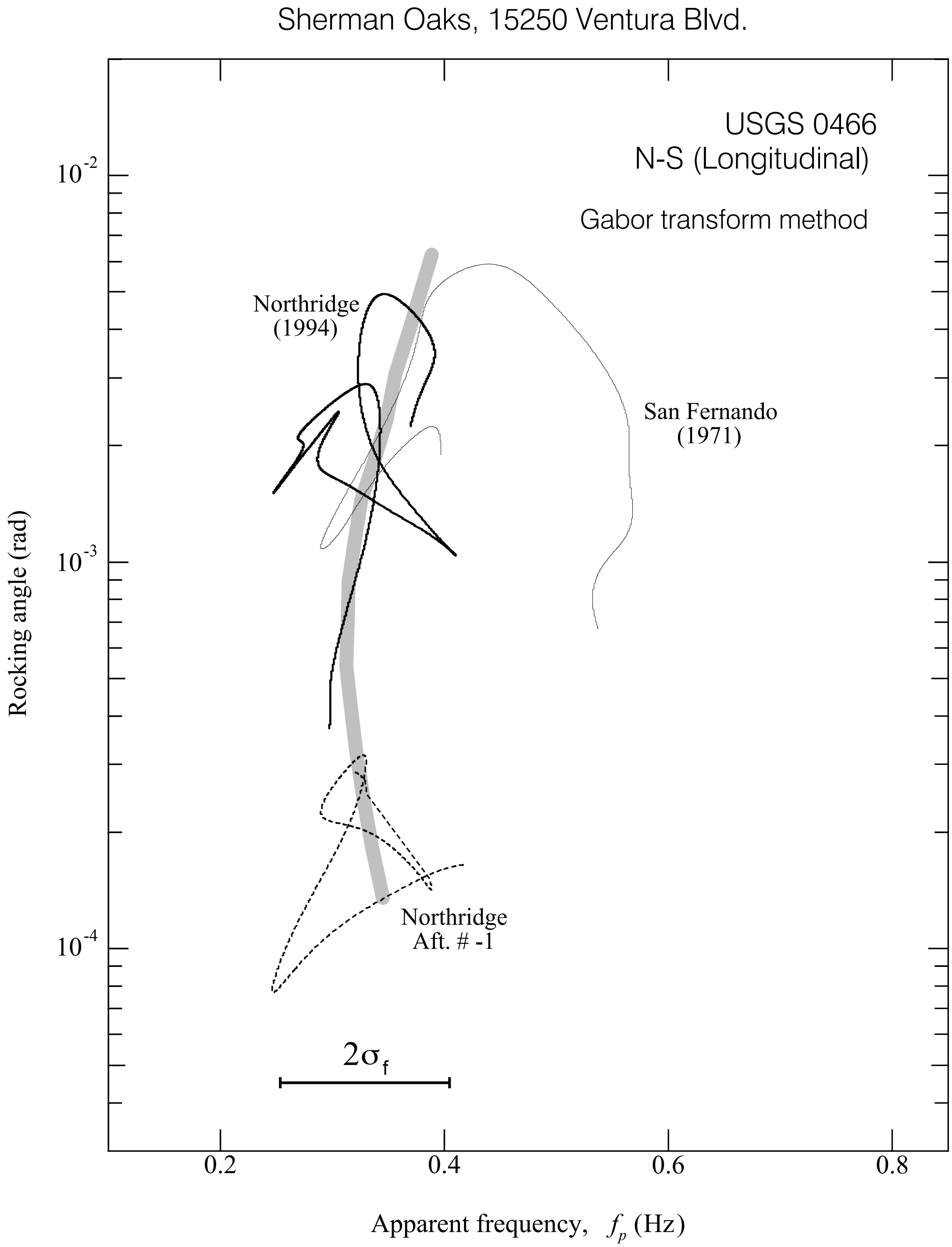


Figure 4.2 Instantaneous frequency versus amplitude of motion for station USGS 466, for N-S vibrations, determined by the Gabor method, for several earthquakes.

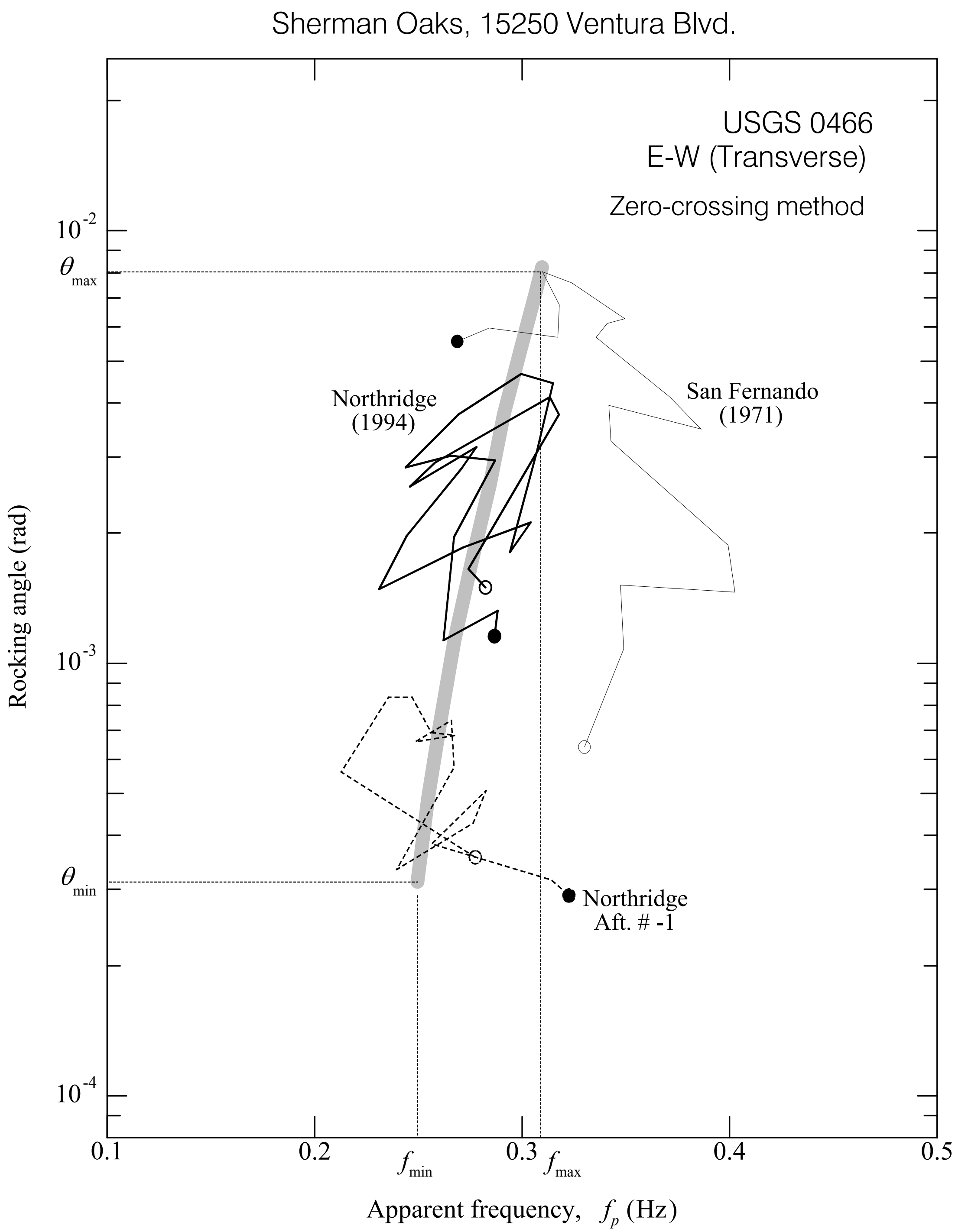


Figure 4.3 Instantaneous frequency versus amplitude of motion for station USGS 466, for E-W vibrations, determined by the zero-crossing method, for several earthquakes.

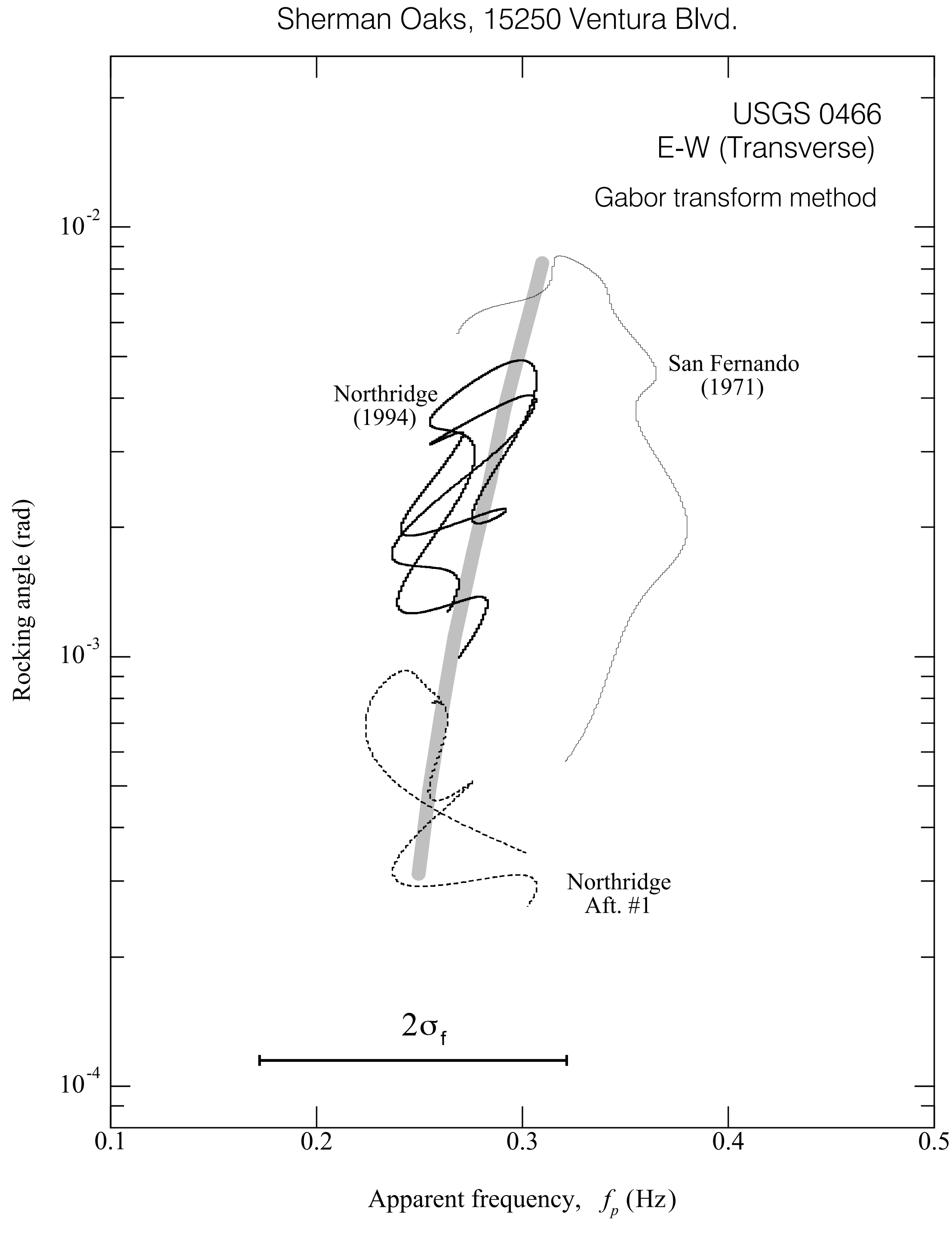


Figure 4.4 Instantaneous frequency versus amplitude of motion for station USGS 466, for E-W vibrations, determined by the Gabor method, for several earthquakes.

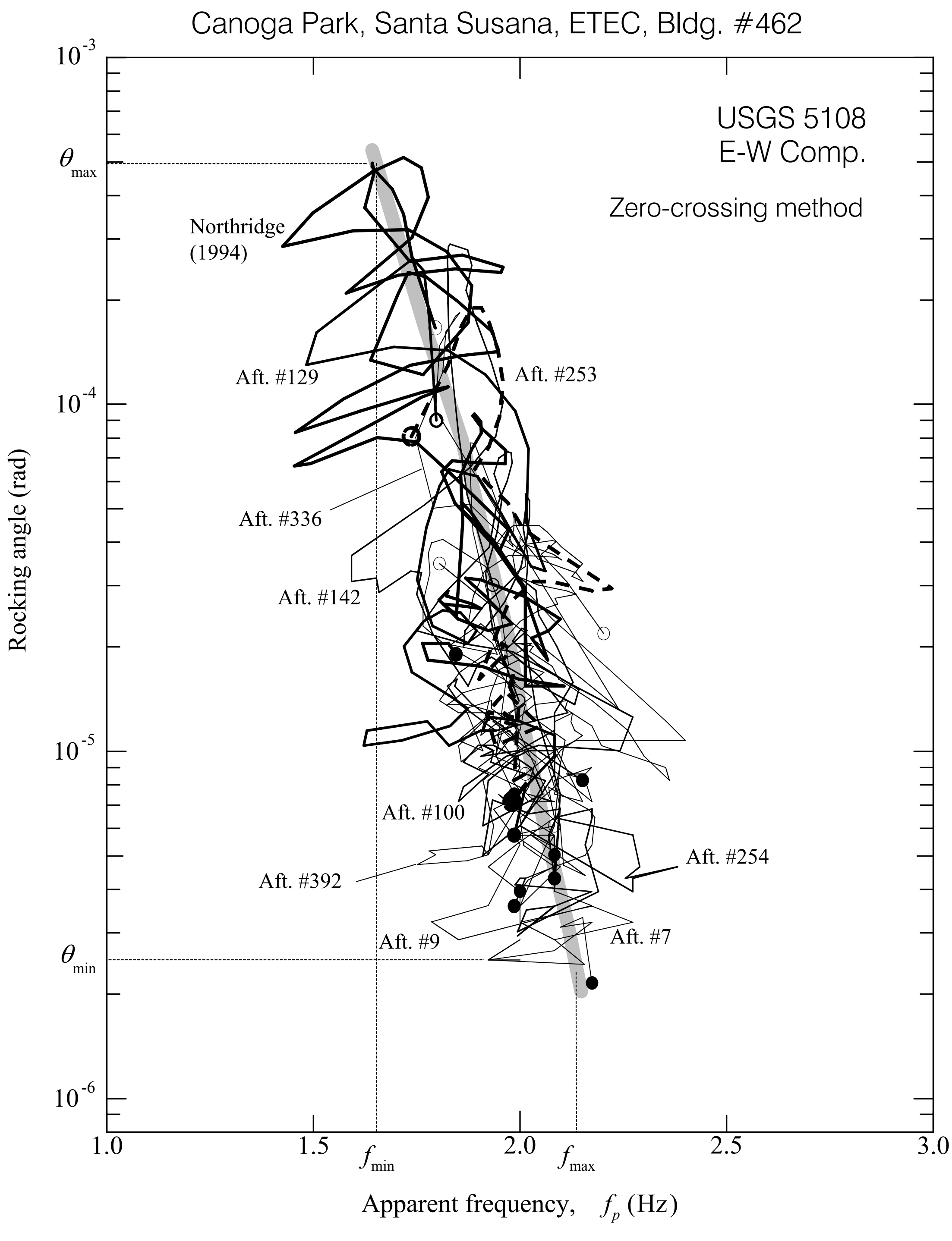


Figure 4.5 Instantaneous frequency versus amplitude of motion for station USGS 5108, for EW vibrations, determined by the zero-crossing method, for several earthquakes.

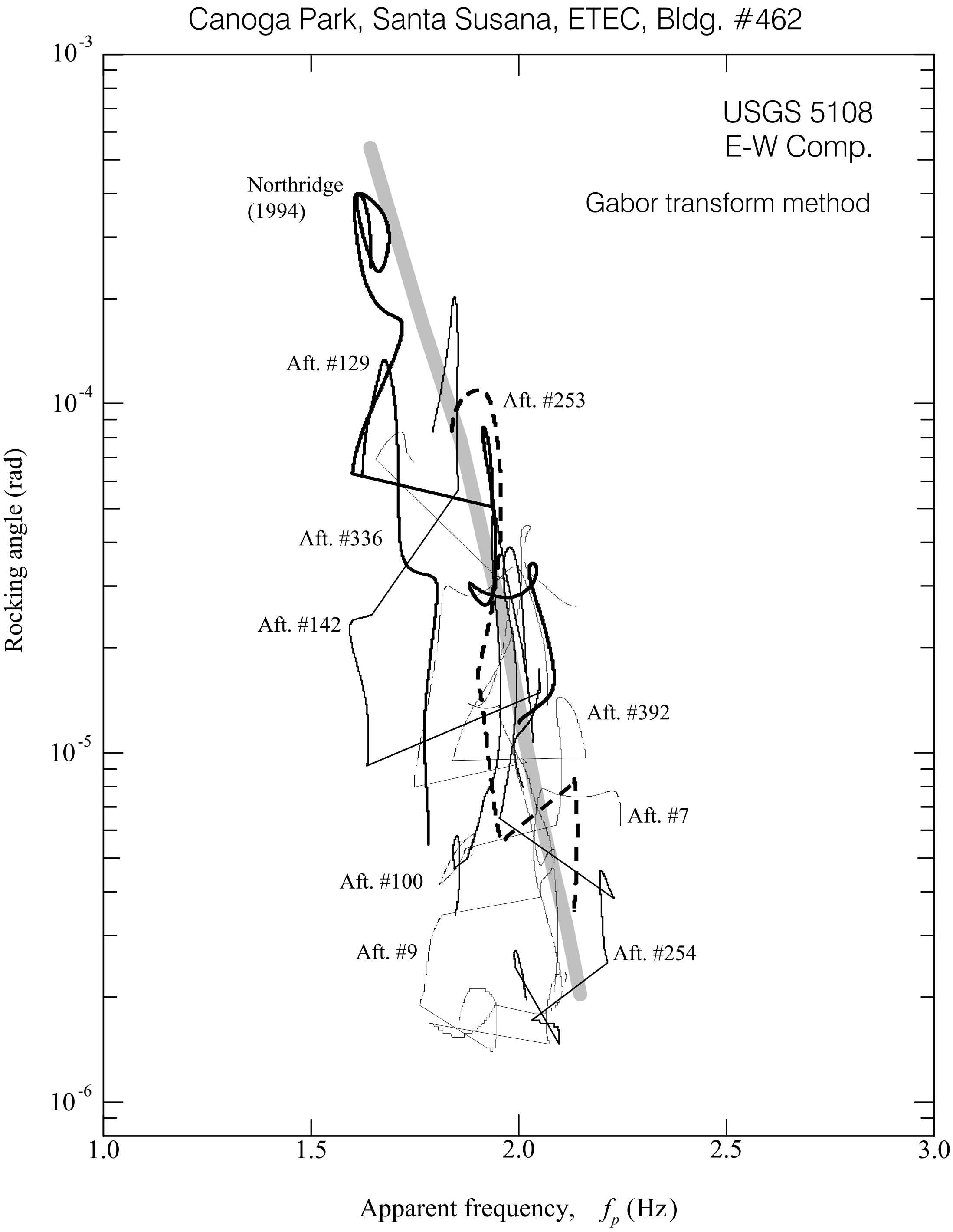


Figure 4.6 Instantaneous frequency versus amplitude of motion for station USGS 5108, for E-W vibrations, determined by the Gabor method, for several earthquakes.

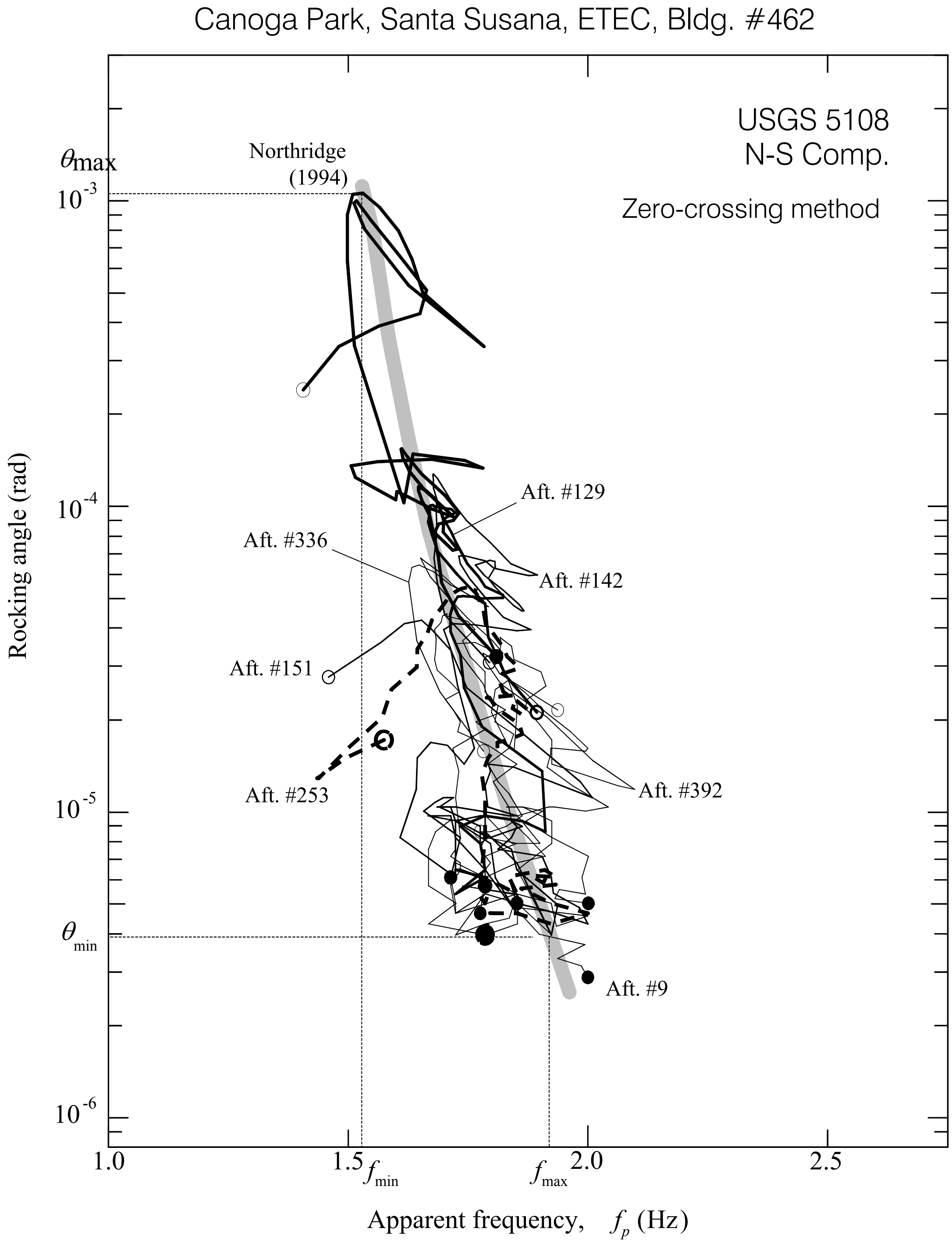


Figure 4.7 Instantaneous frequency versus amplitude of motion for station USGS 5108, for N-S vibrations, determined by the zero-crossing method, for several earthquakes.

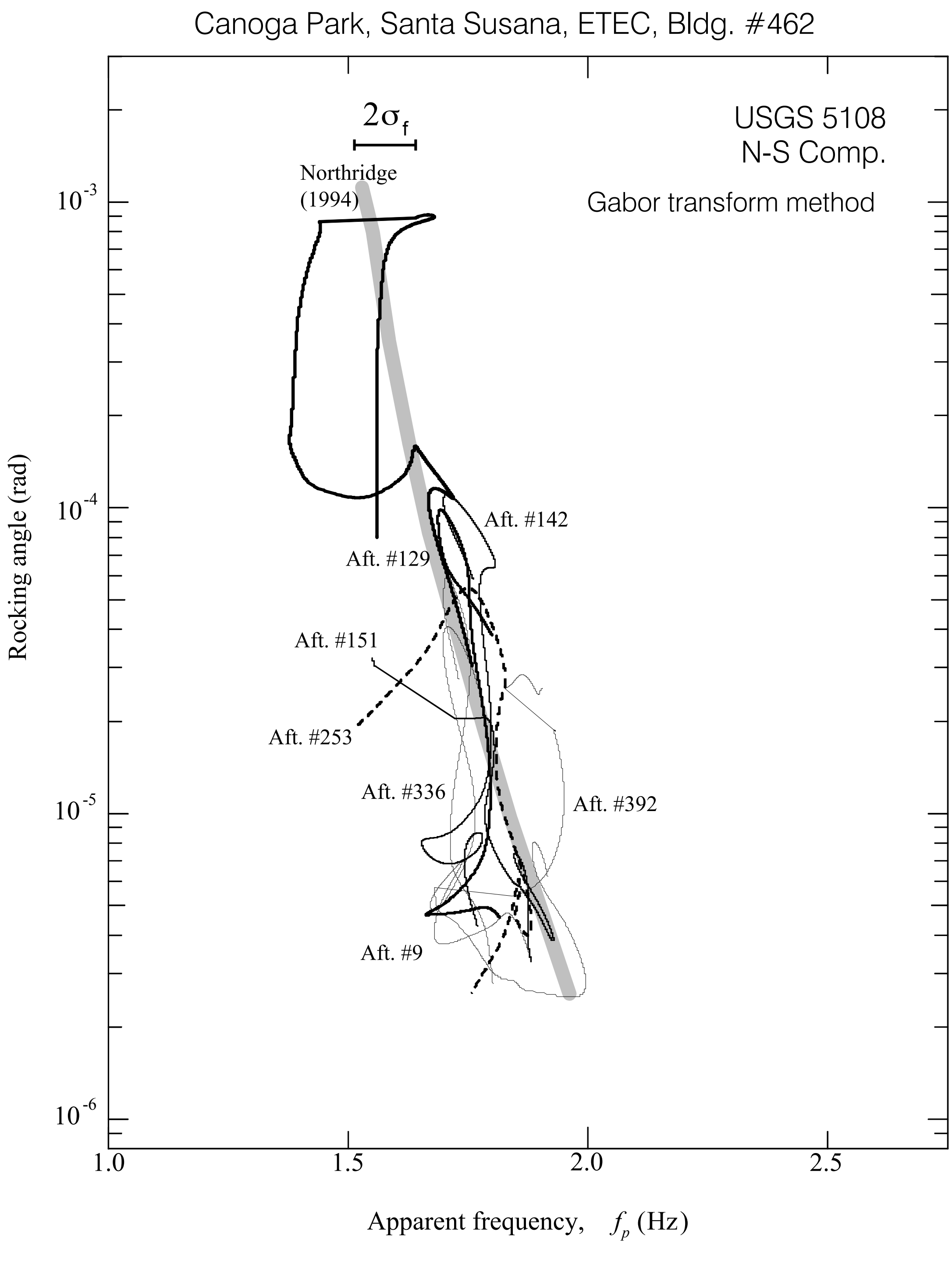


Figure 4.8 Instantaneous frequency versus amplitude of motion for station USGS 5108, for N-S vibrations, determined by the Gabor method, for several earthquakes.

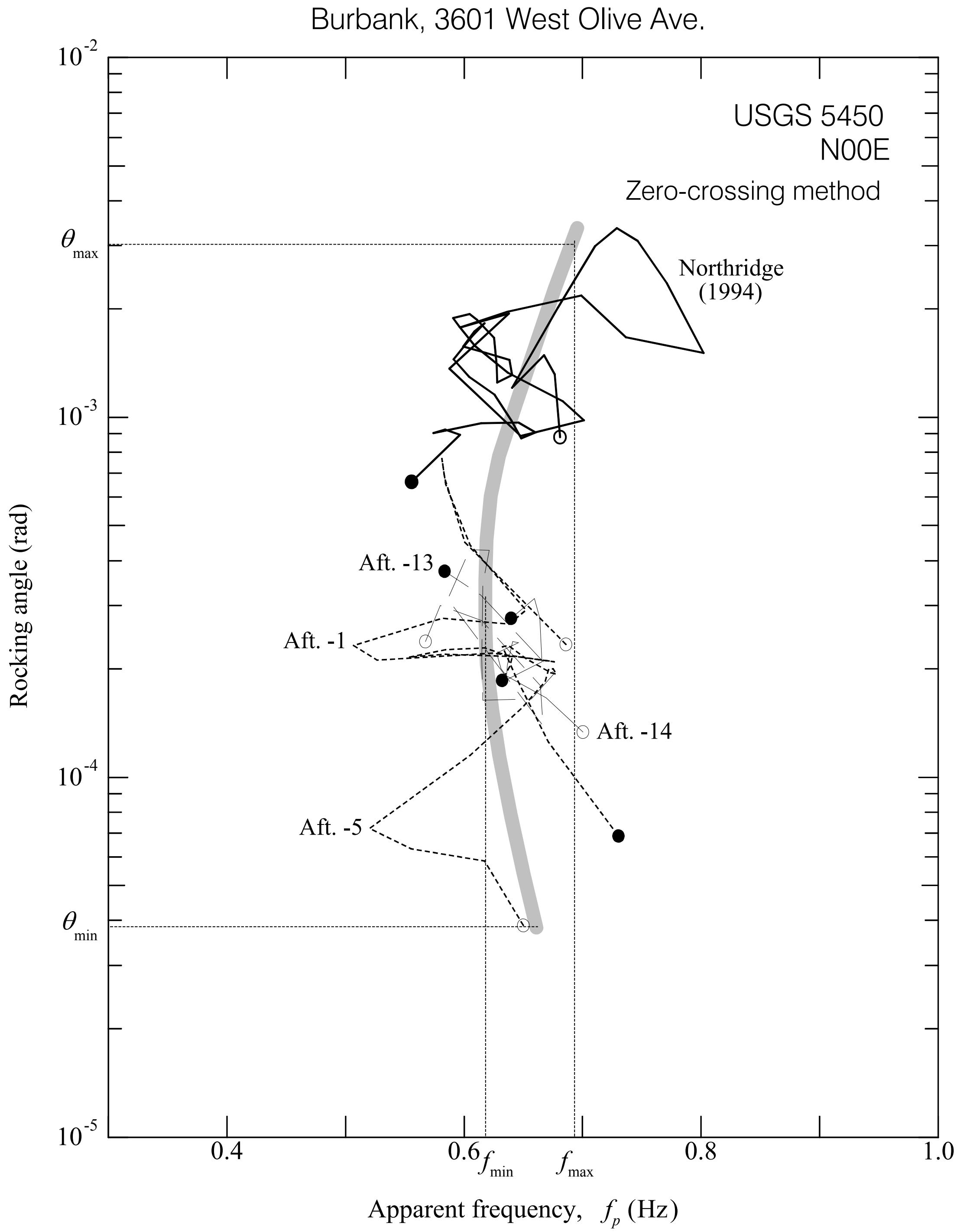


Figure 4.9 Instantaneous frequency versus amplitude of motion for station USGS 5450, for N00E vibrations, determined by the zero-crossing method, for several earthquakes.

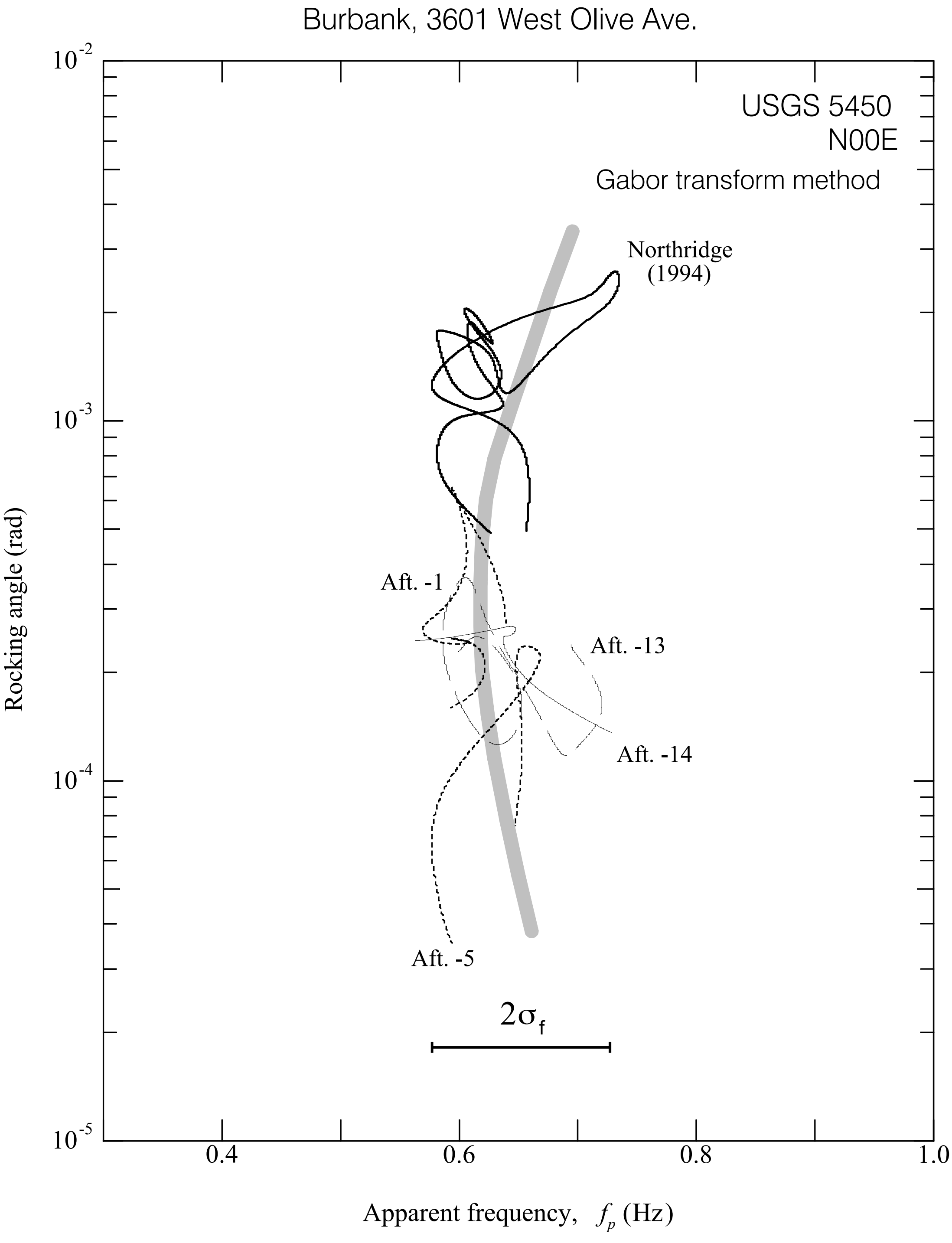


Figure 4.10 Instantaneous frequency versus amplitude of motion for station USGS 5450, for N00E vibrations, determined by the Gabor method, for several earthquakes.

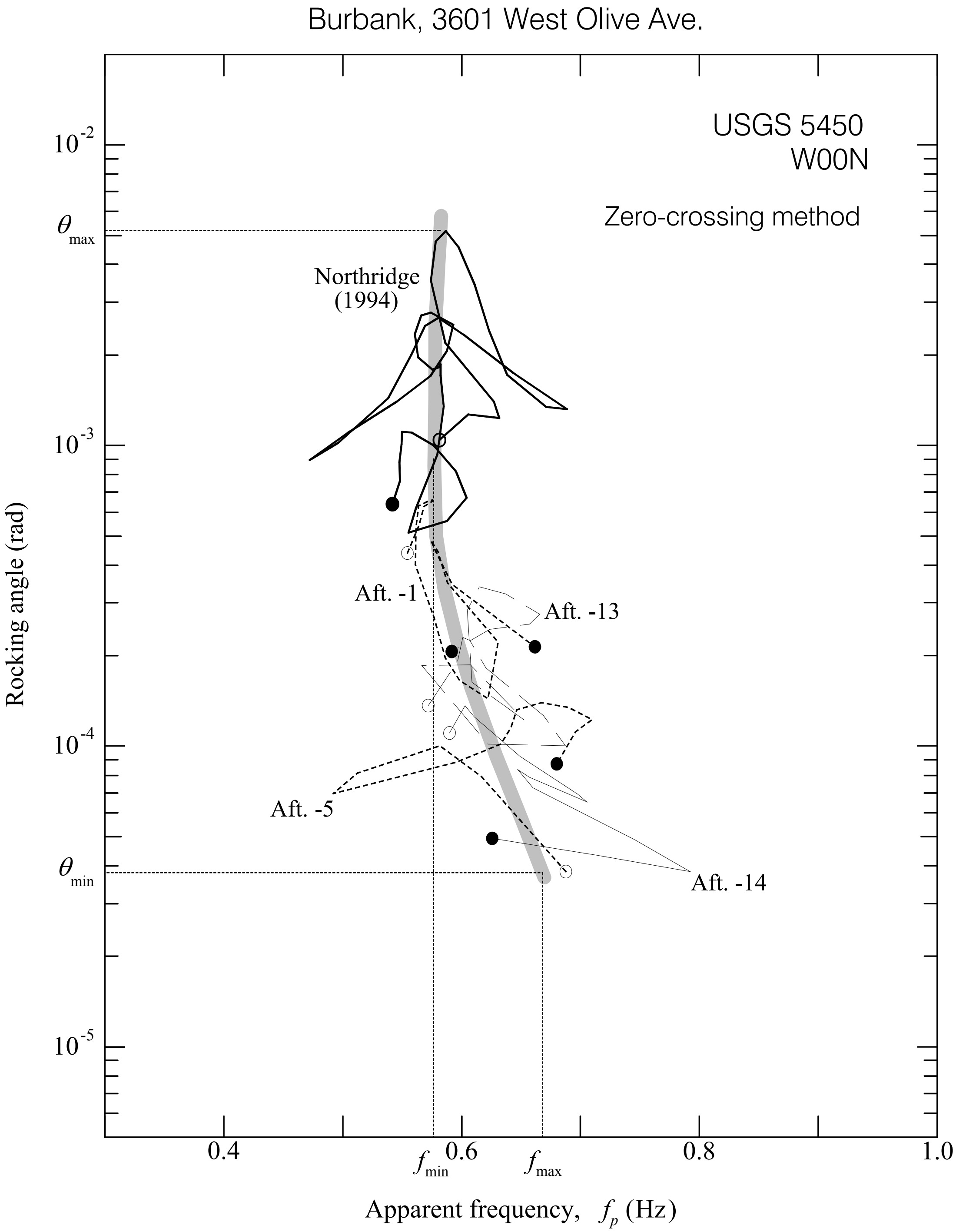


Figure 4.11 Instantaneous frequency versus amplitude of motion for station USGS 5450, for W00N vibrations, determined by the zero-crossing method, for several earthquakes.

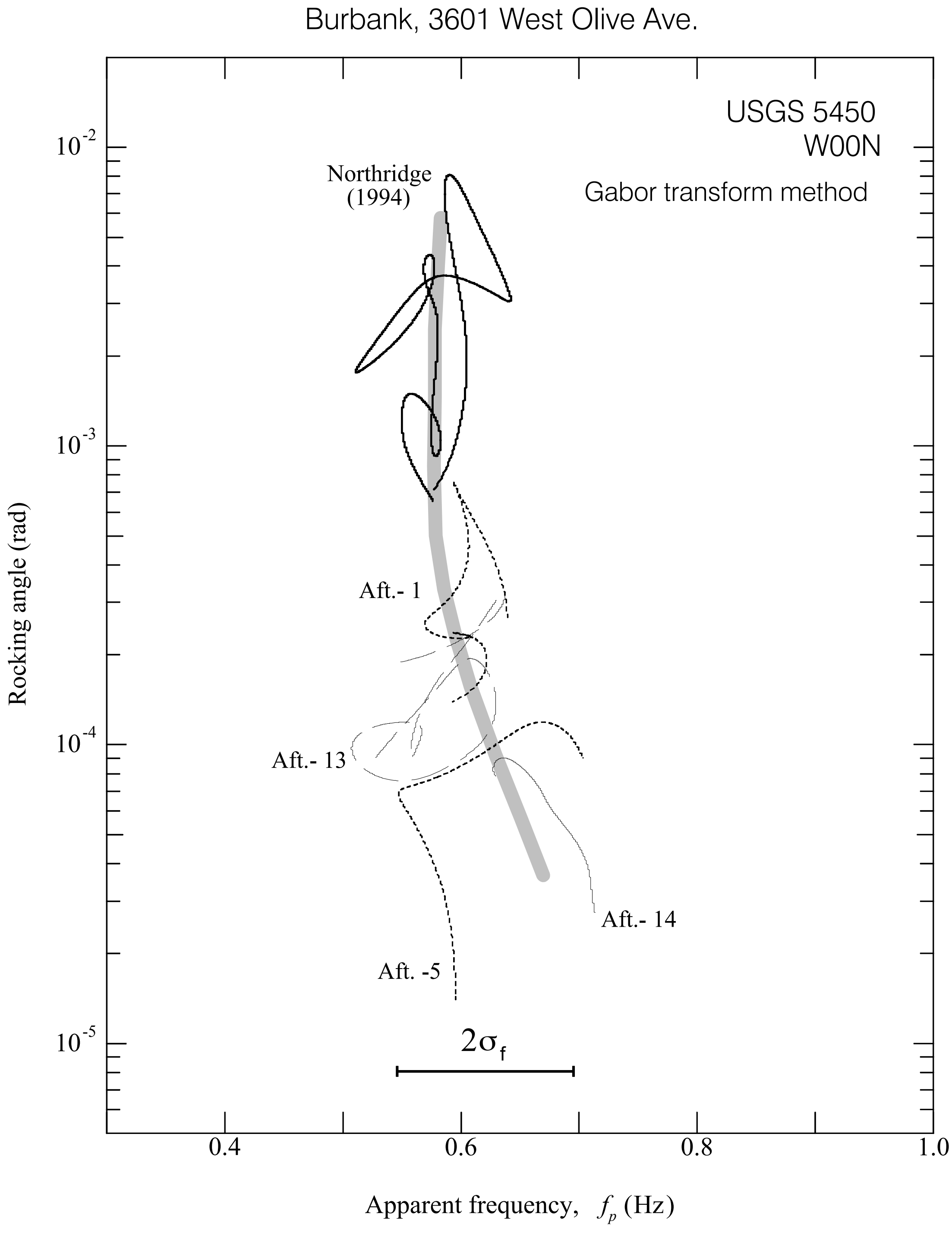


Figure 4.12 Instantaneous frequency versus amplitude of motion for station USGS 5450, for W00N vibrations, determined by the Gabor method, for several earthquakes.

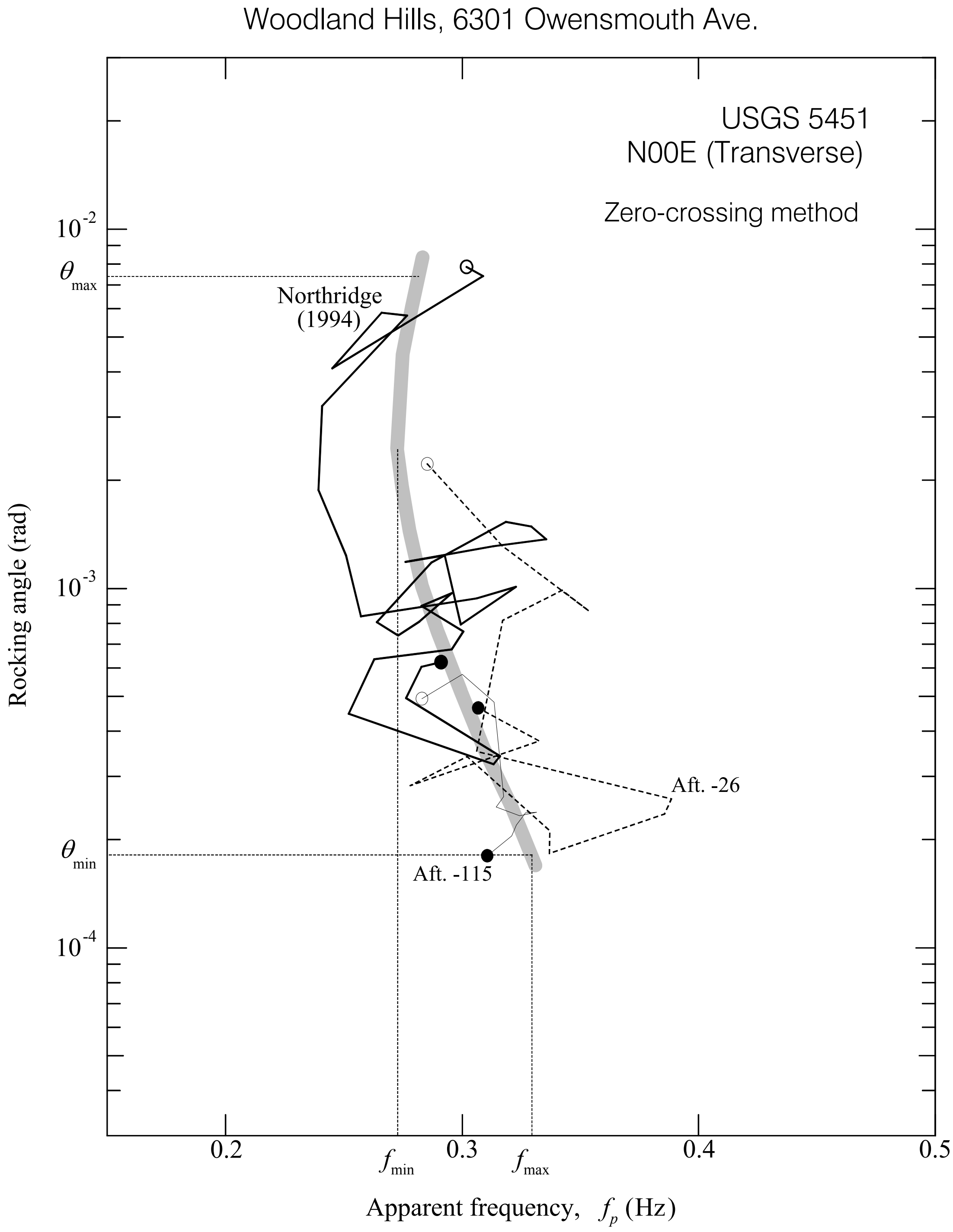


Figure 4.13 Instantaneous frequency versus amplitude of motion for station USGS 5451, for N00E vibrations, determined by the zero-crossing method, for several earthquakes.

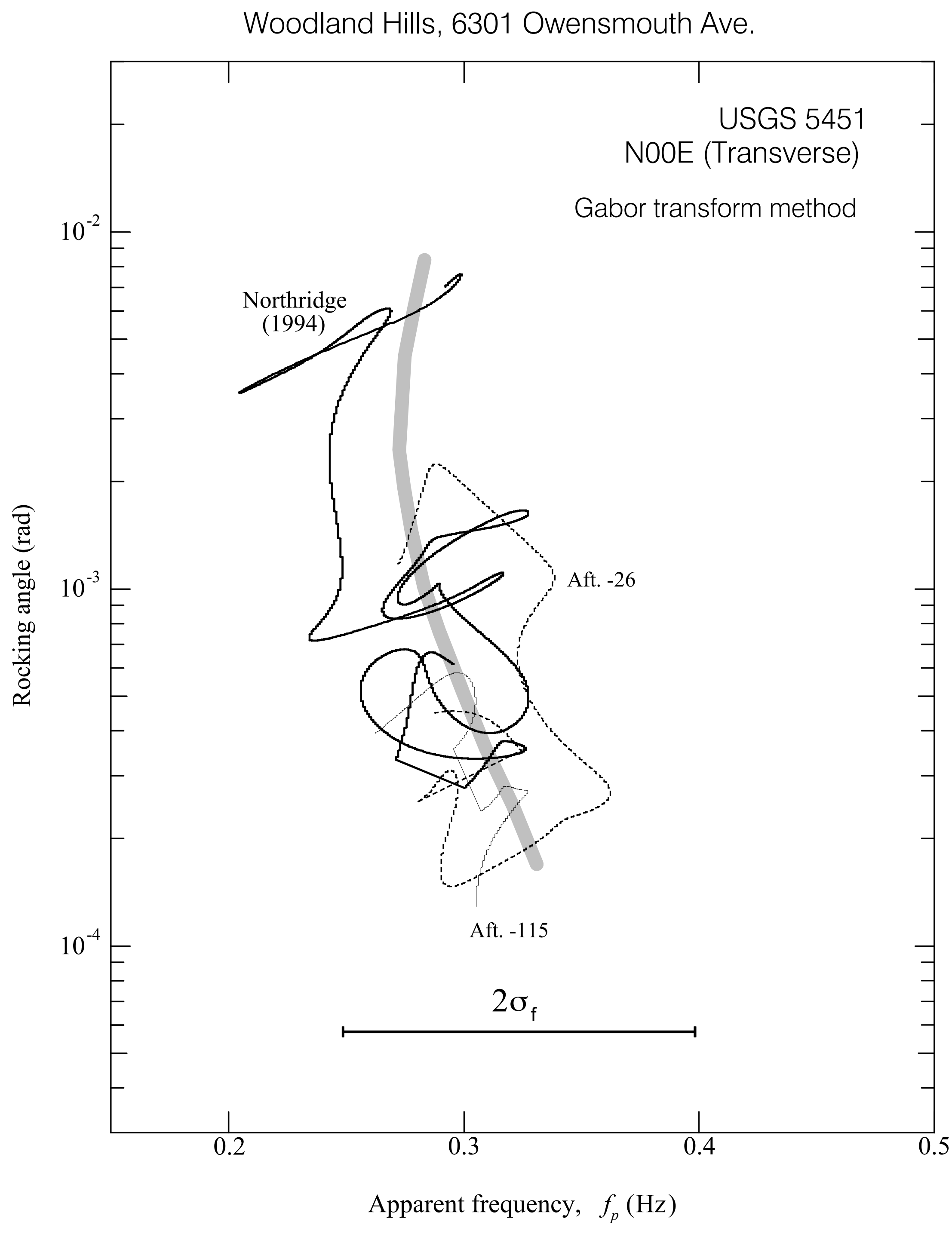


Figure 4.14 Instantaneous frequency versus amplitude of motion for station USGS 5451, for N00E vibrations, determined by the Gabor method, for several earthquakes.

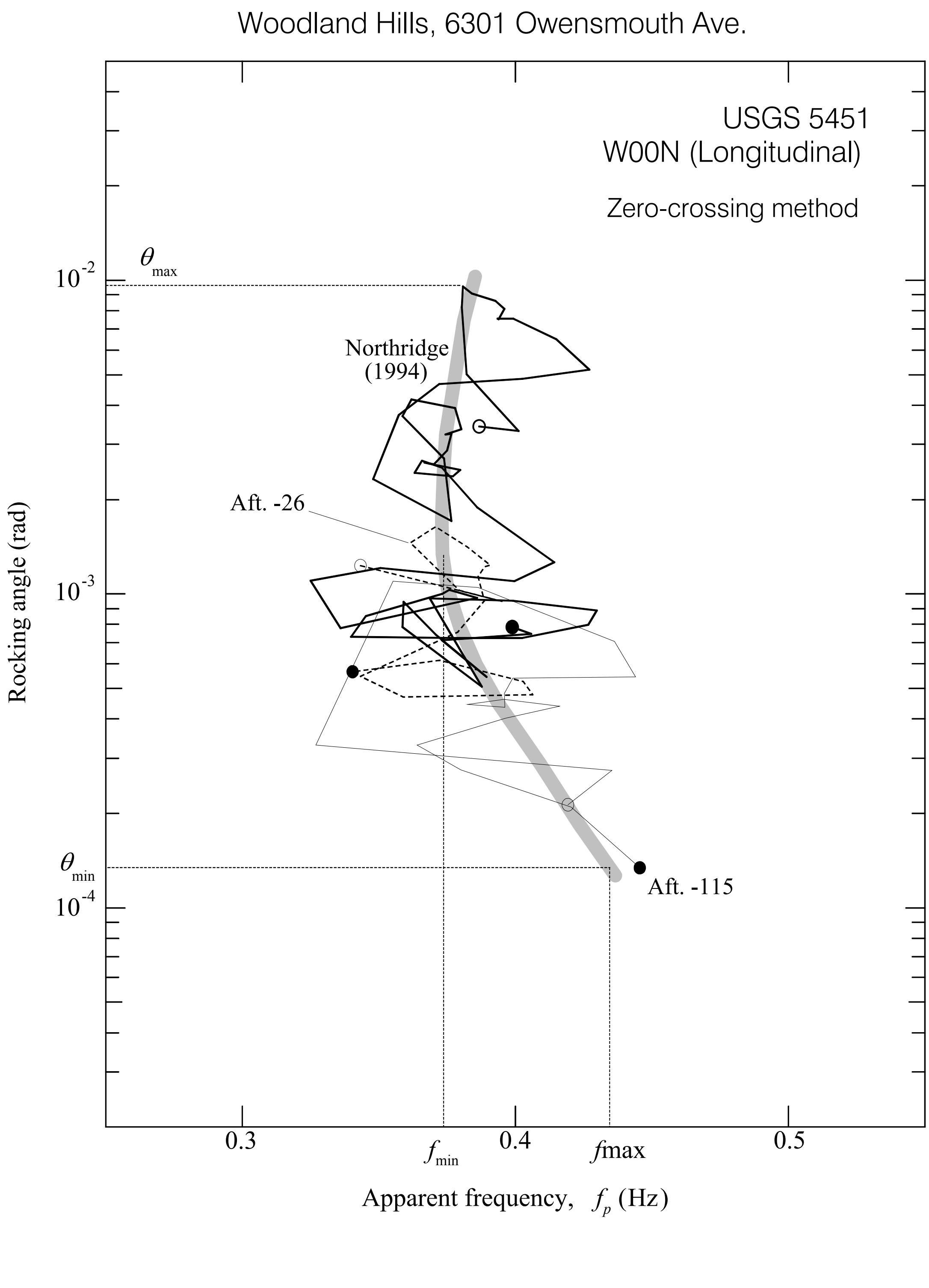


Figure 4.15 Instantaneous frequency versus amplitude of motion for station USGS 5451, for W00N vibrations, determined by the zero-crossing method, for several earthquakes.

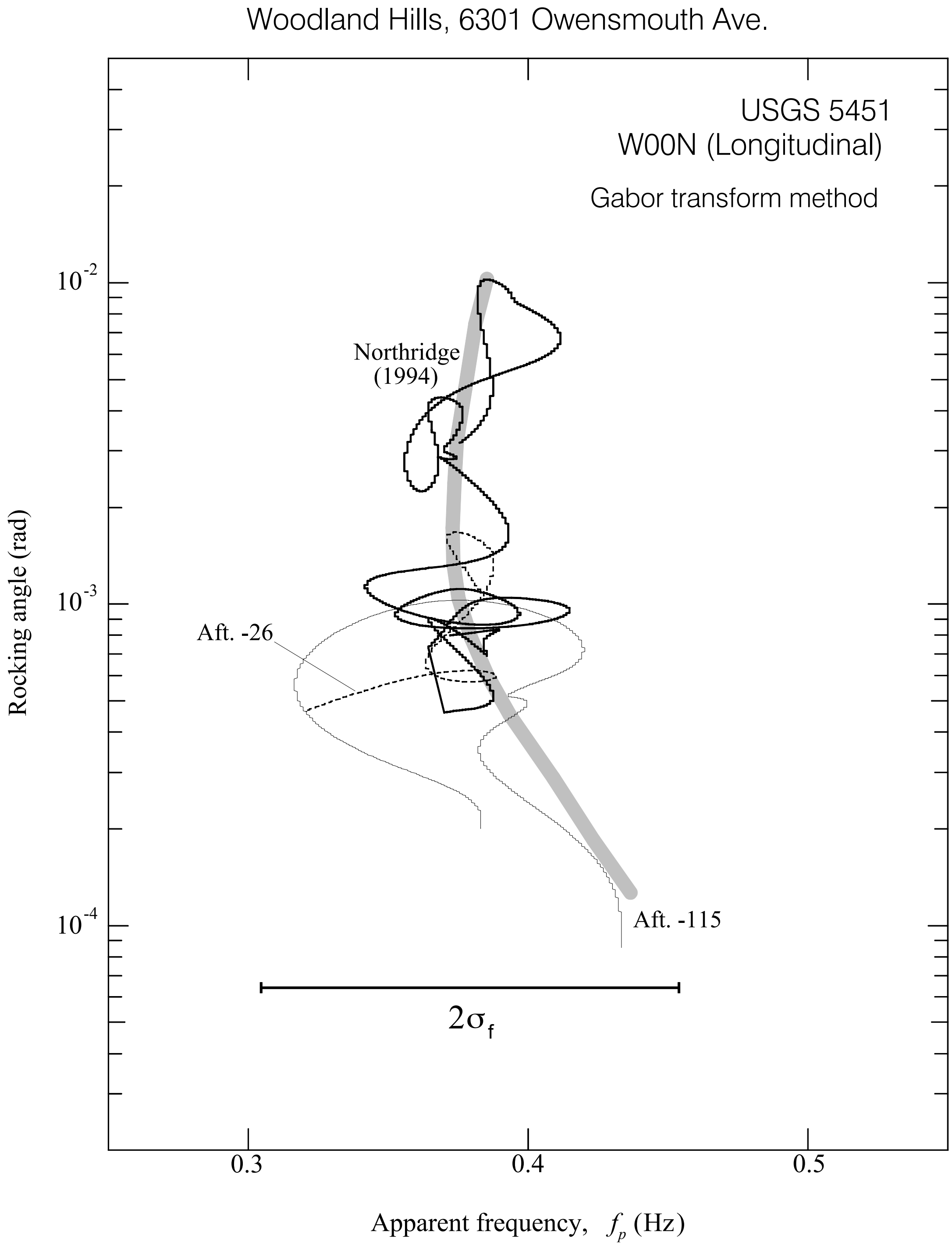


Figure 4.16 Instantaneous frequency versus amplitude of motion for station USGS 5451, for W00N vibrations, determined by the Gabor method, for several earthquakes.

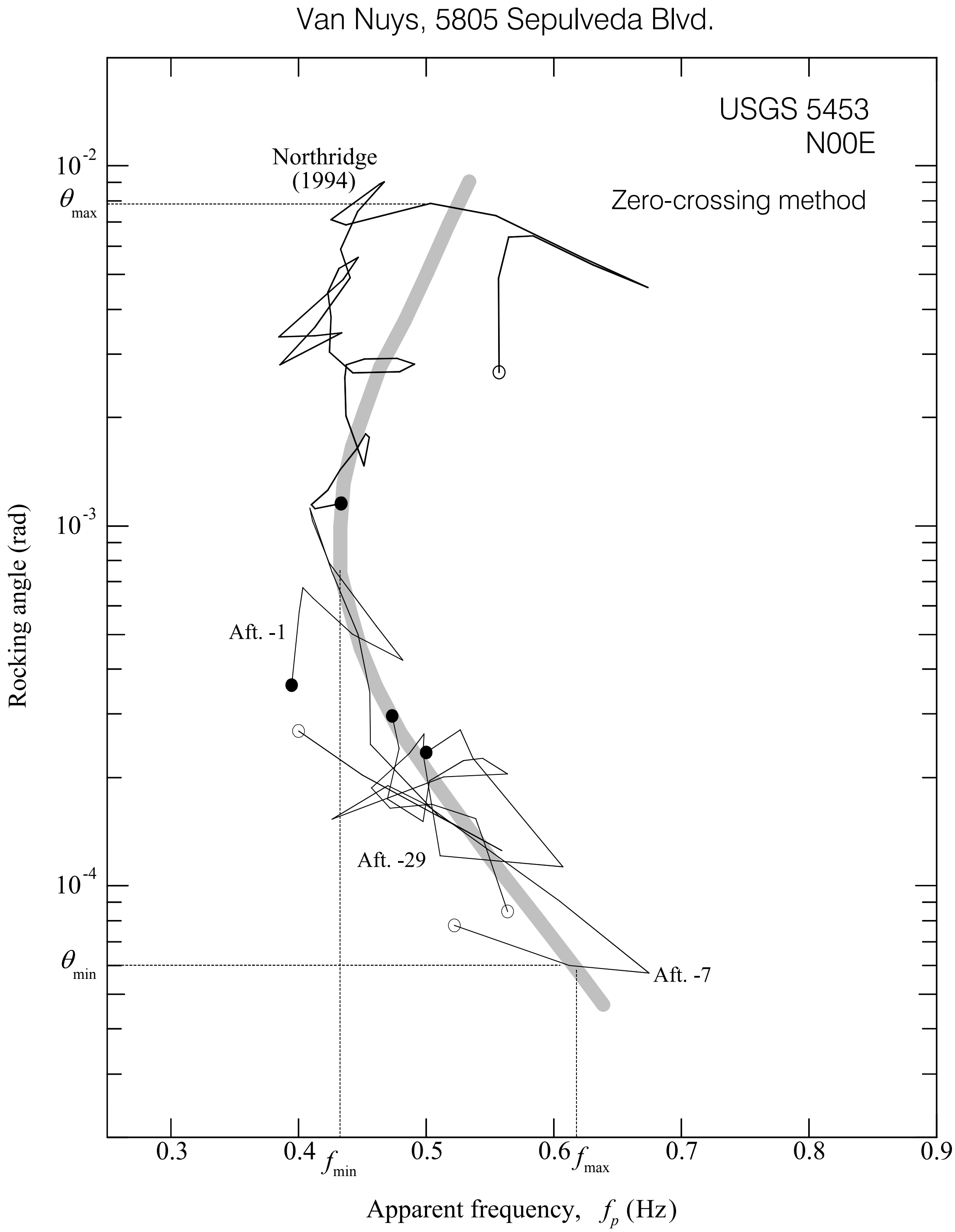


Figure 4.17 Instantaneous frequency versus amplitude of motion for station USGS 5453, for N00E vibrations, determined by the zero-crossing method, for several earthquakes.

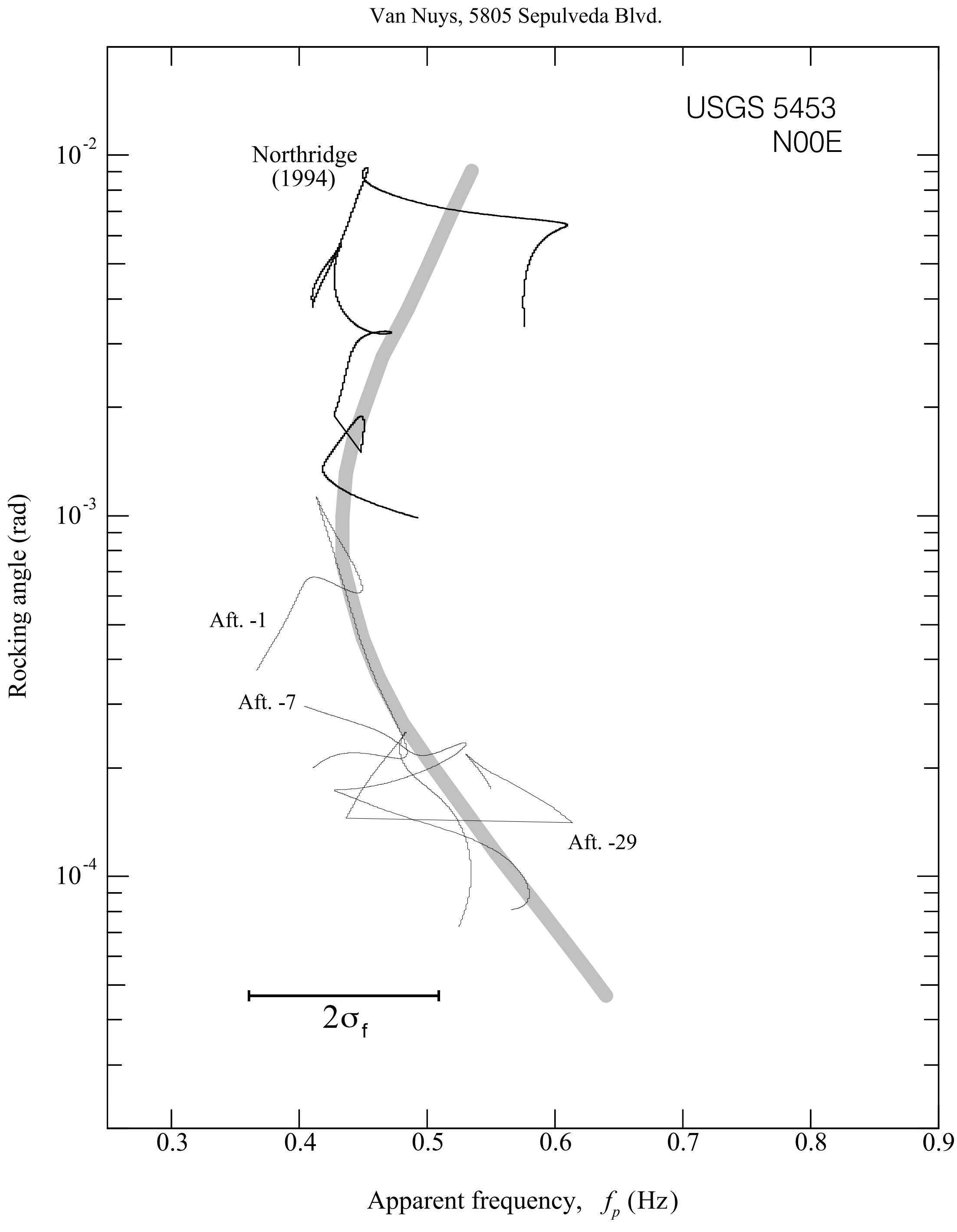


Figure 4.18 Instantaneous frequency versus amplitude of motion for station USGS 5453, for N00E vibrations, determined by the Gabor method, for several earthquakes.

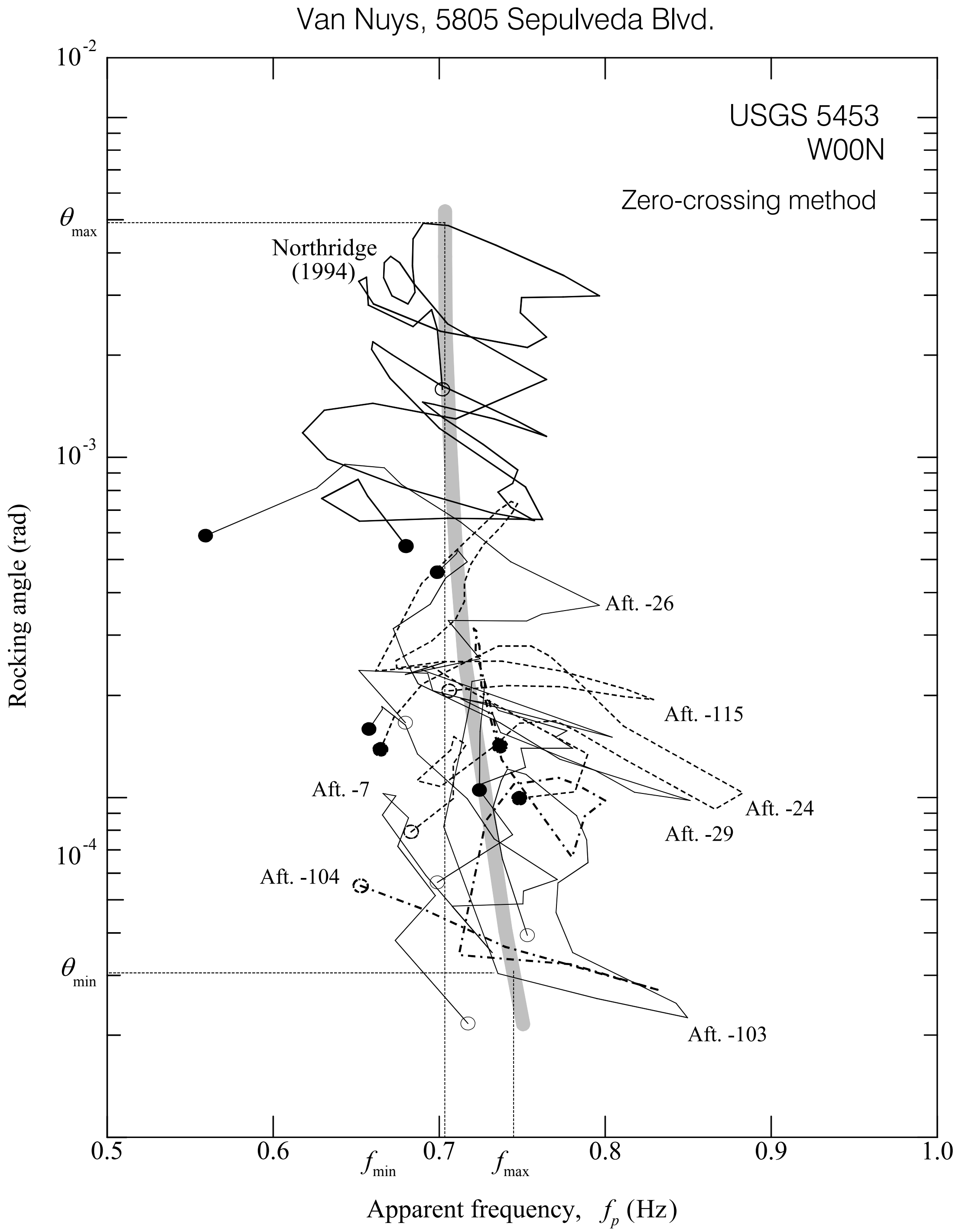


Figure 4.19 Instantaneous frequency versus amplitude of motion for station USGS 5453, for W00N vibrations, determined by the zero-crossing method, for several earthquakes.

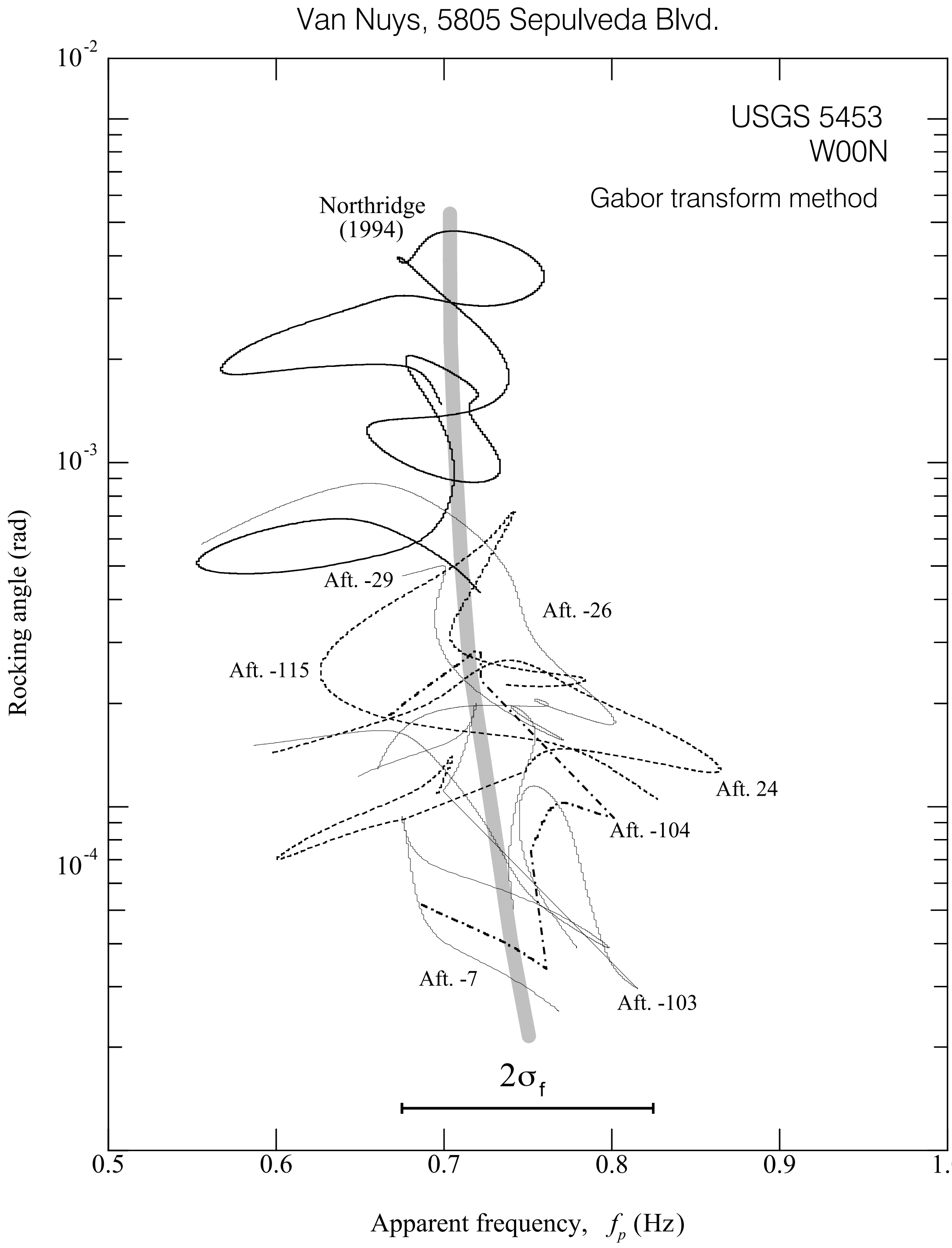


Figure 4.20 Instantaneous frequency versus amplitude of motion for station USGS 5453, for W00N vibrations, determined by the Gabor method, for several earthquakes.

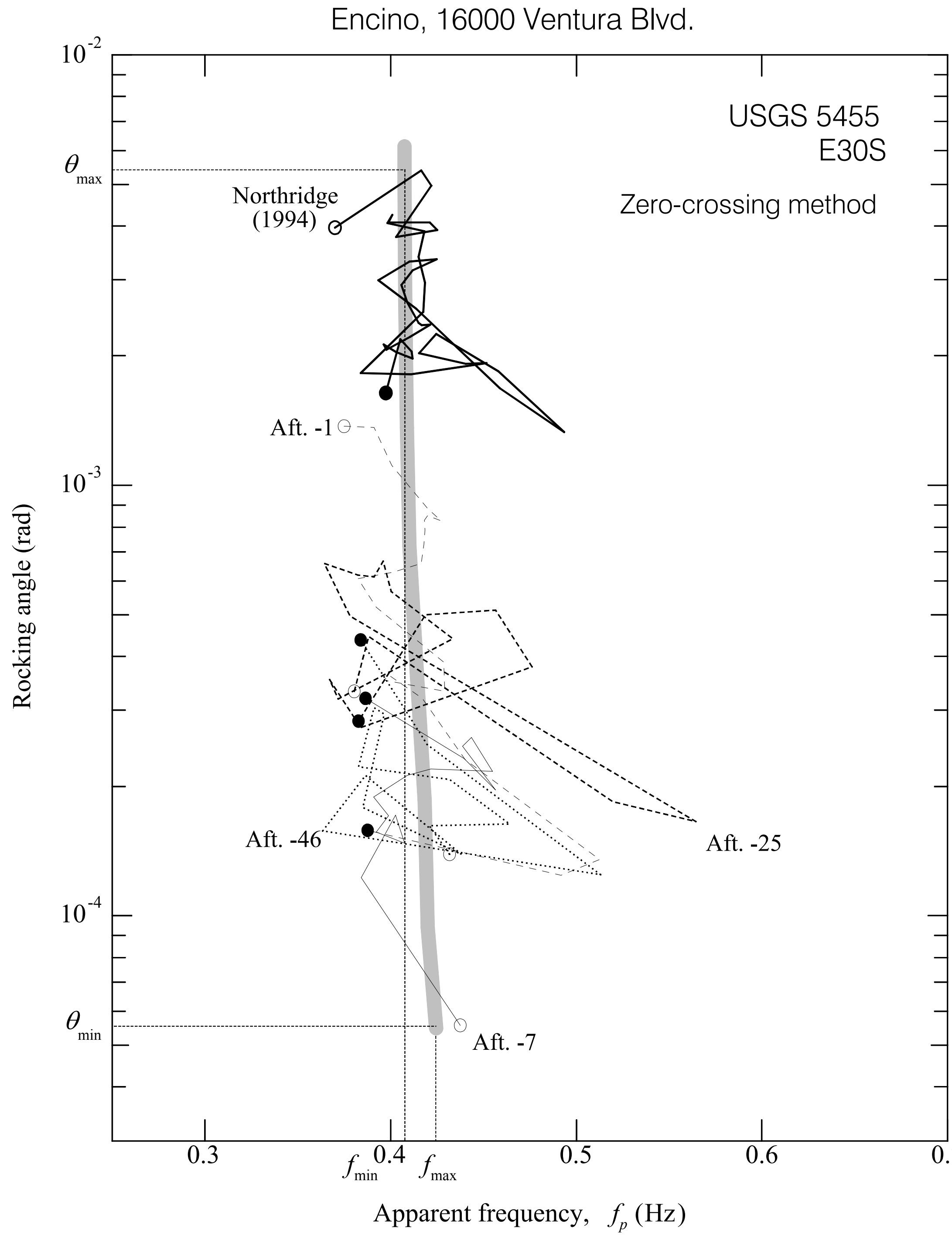


Figure 4.21 Instantaneous frequency versus amplitude of motion for station USGS 5455, for E30S vibrations, determined by the zero-crossing method, for several earthquakes.

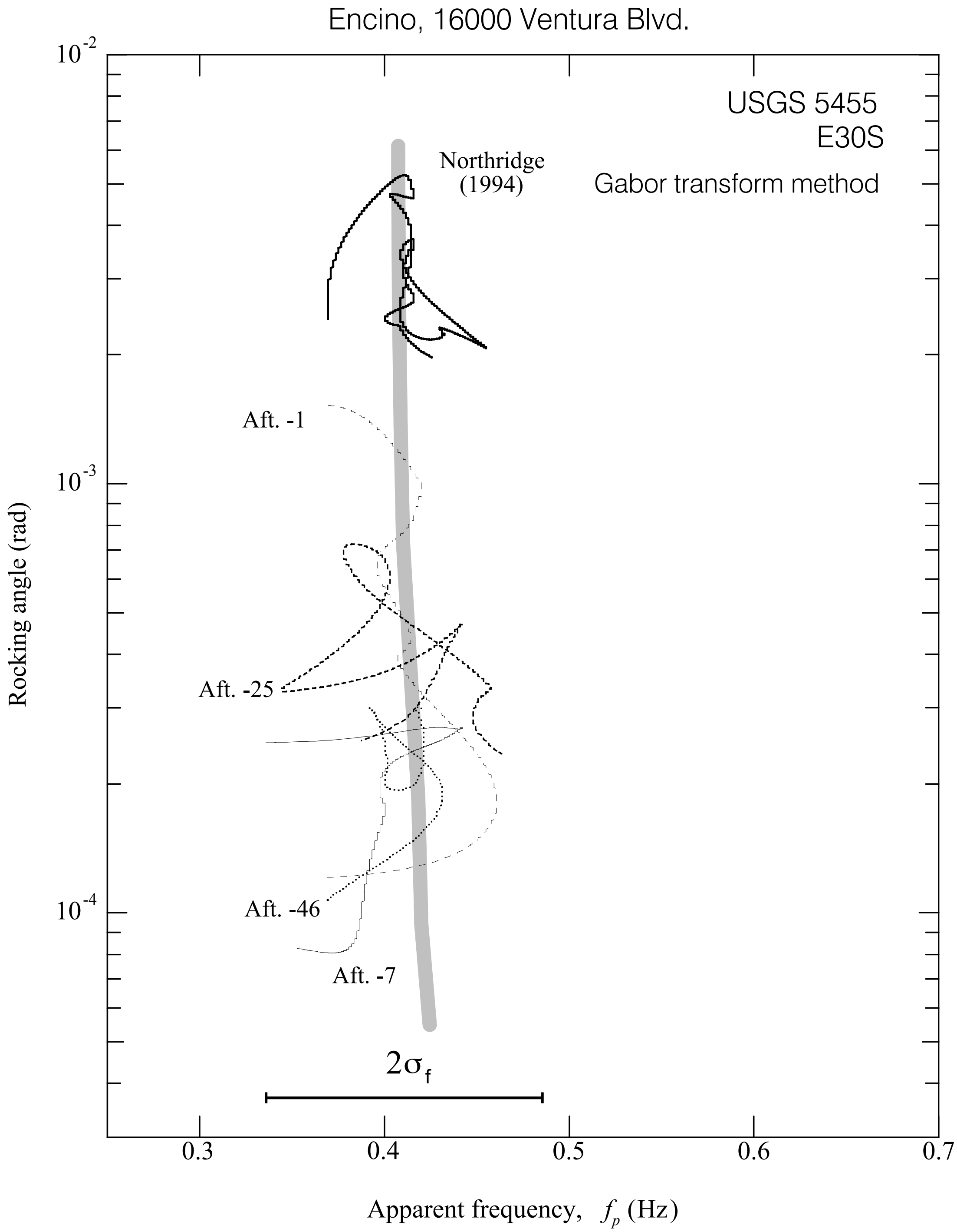


Figure 4.22 Instantaneous frequency versus amplitude of motion for station USGS 5455, for E30S vibrations, determined by the Gabor method, for several earthquakes.

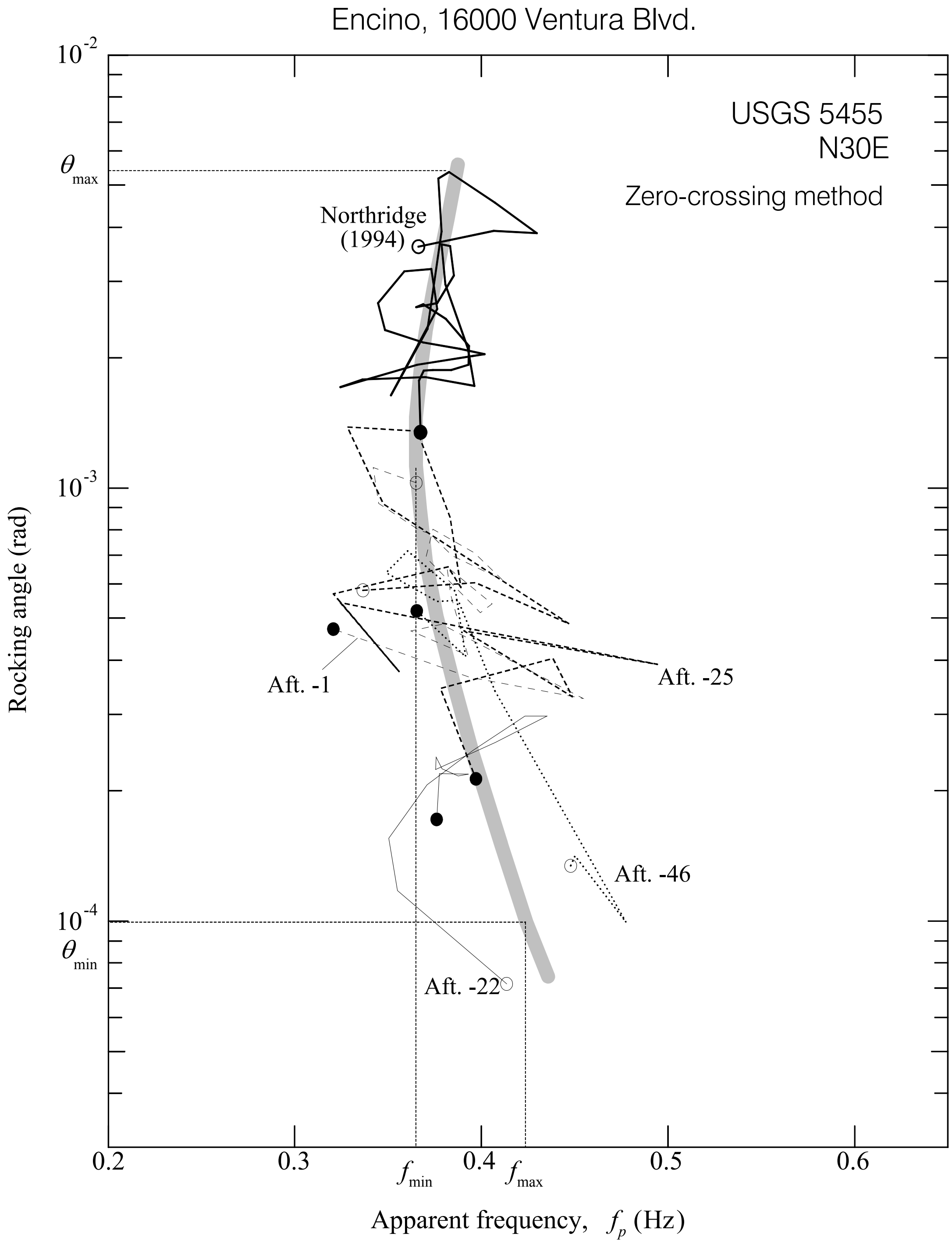


Figure 4.23 Instantaneous frequency versus amplitude of motion for station USGS 5455, for N30E vibrations, determined by the zero-crossing method, for several earthquakes.

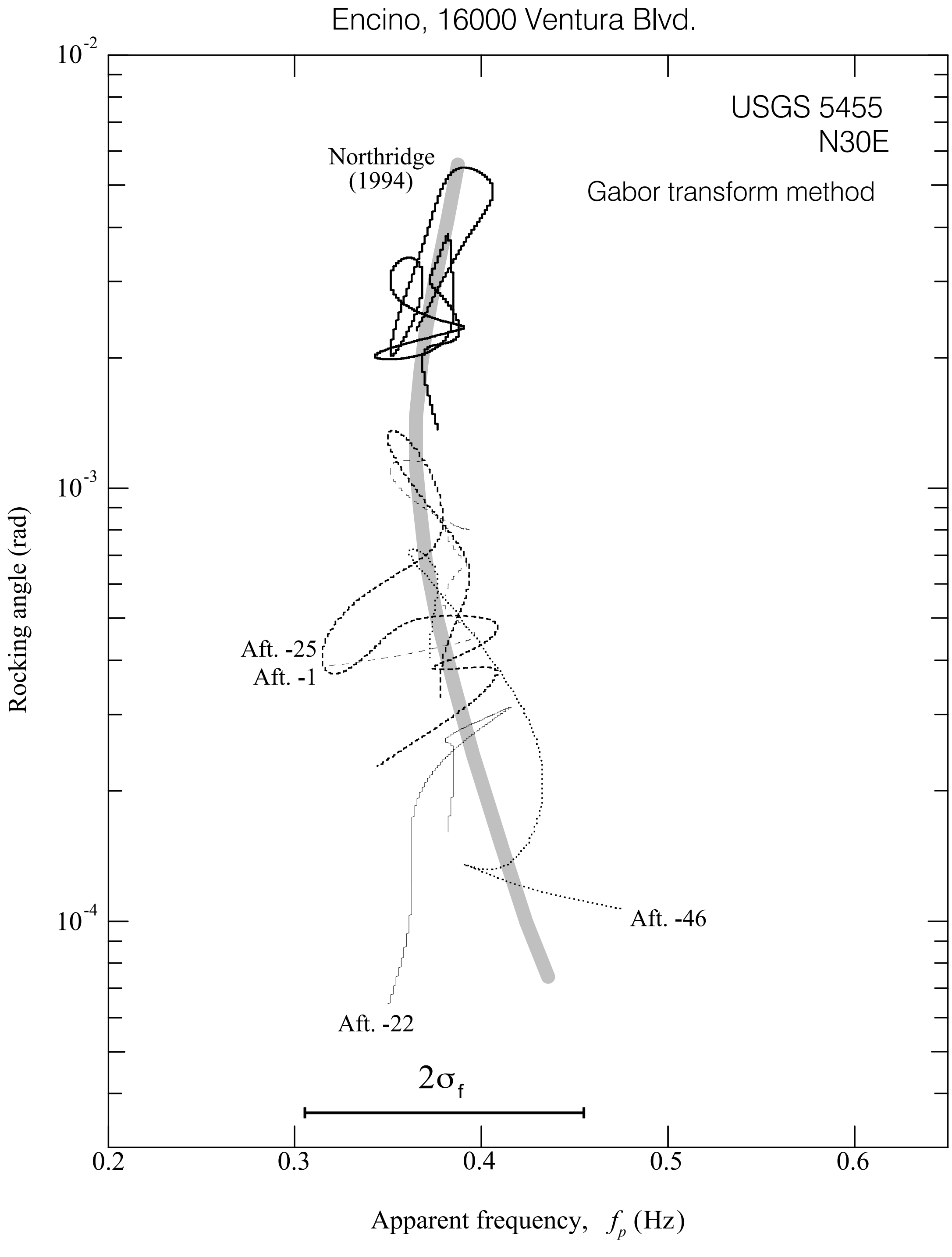


Figure 4.24 Instantaneous frequency versus amplitude of motion for station USGS 5455, for N30E vibrations, determined by the Gabor method, for several earthquakes.

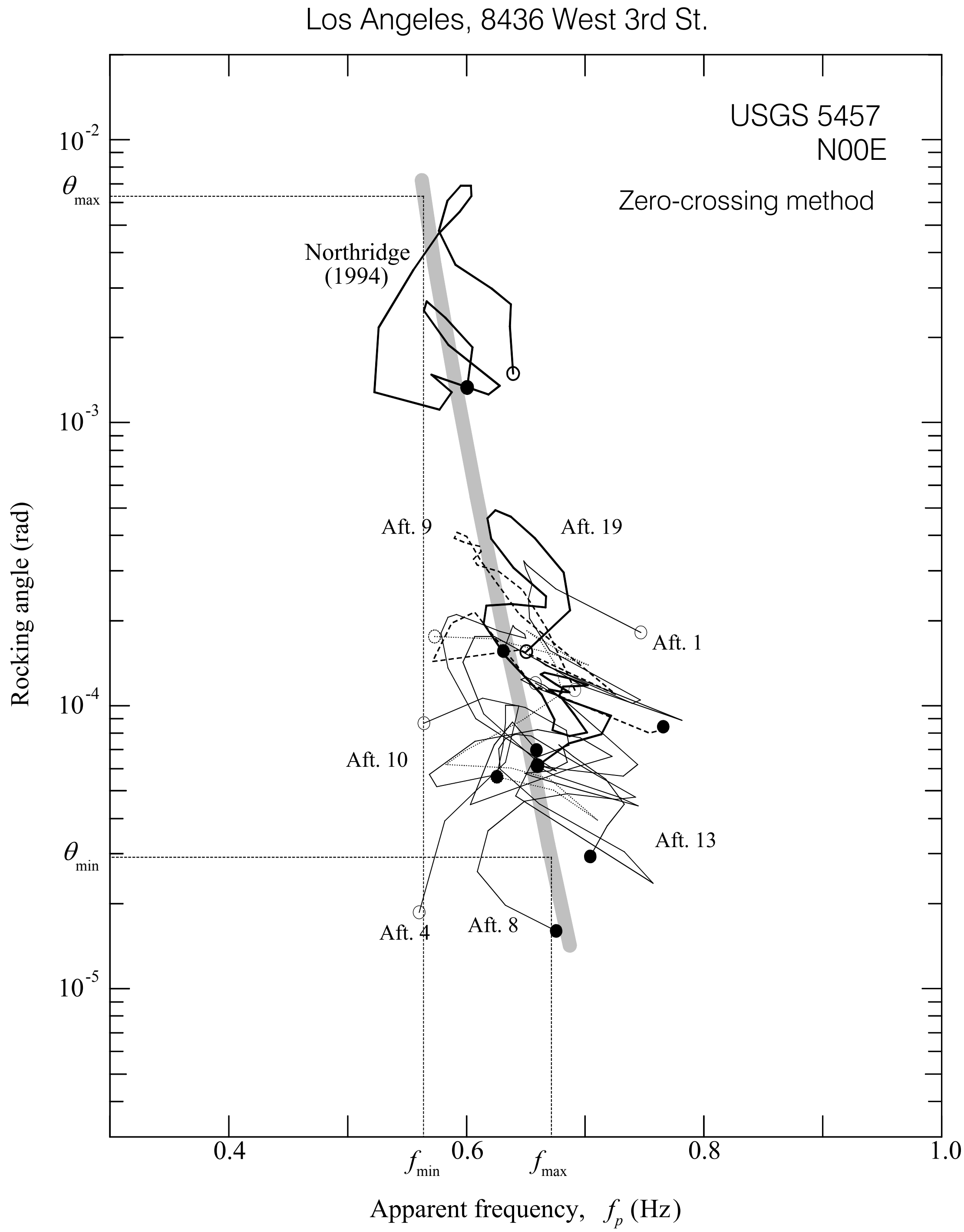


Figure 4.25 Instantaneous frequency versus amplitude of motion for station USGS 5457, for N00E vibrations, determined by the zero-crossing method, for several earthquakes.

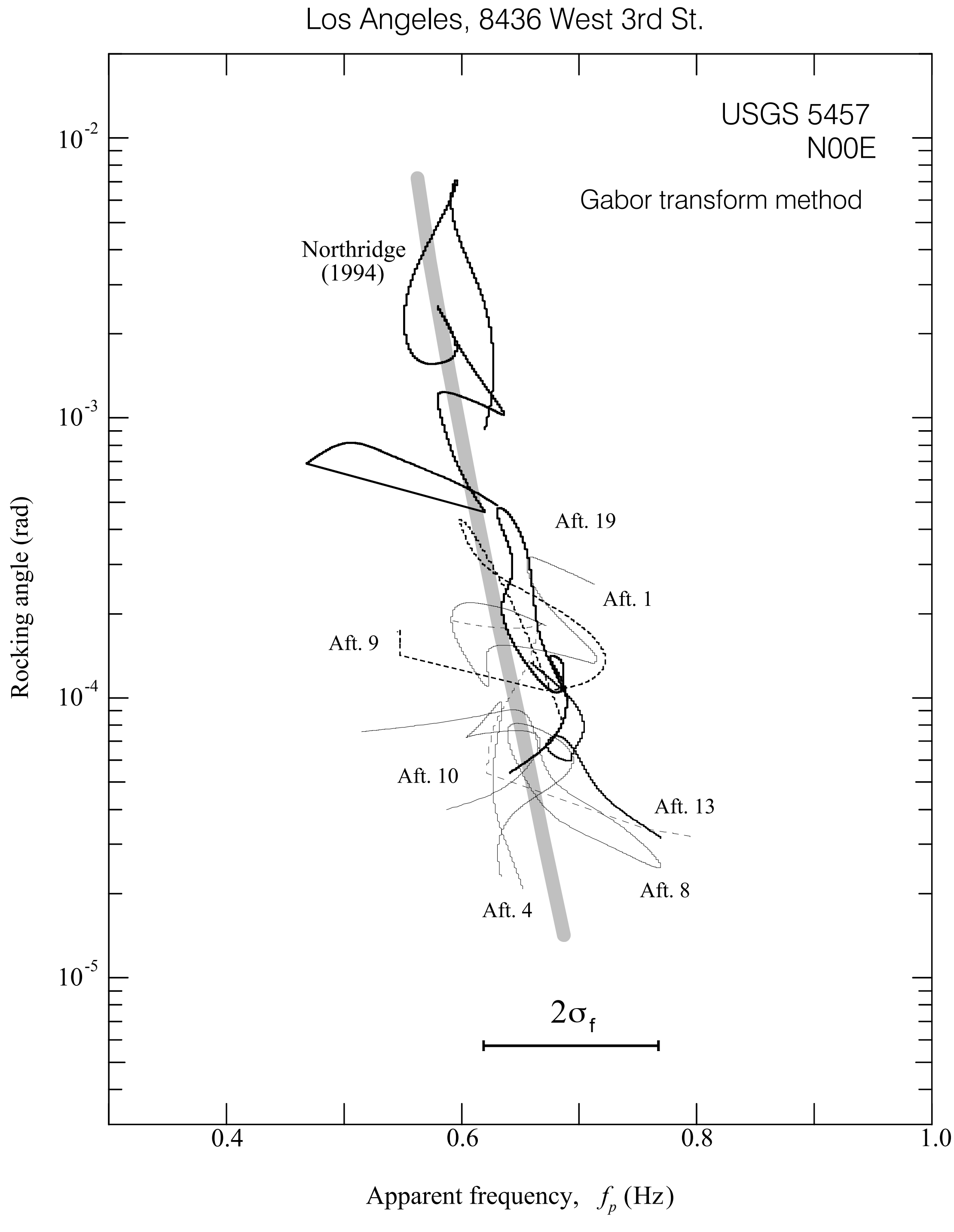


Figure 4.26 Instantaneous frequency versus amplitude of motion for station USGS 5457, for N00E vibrations, determined by the Gabor method, for several earthquakes.

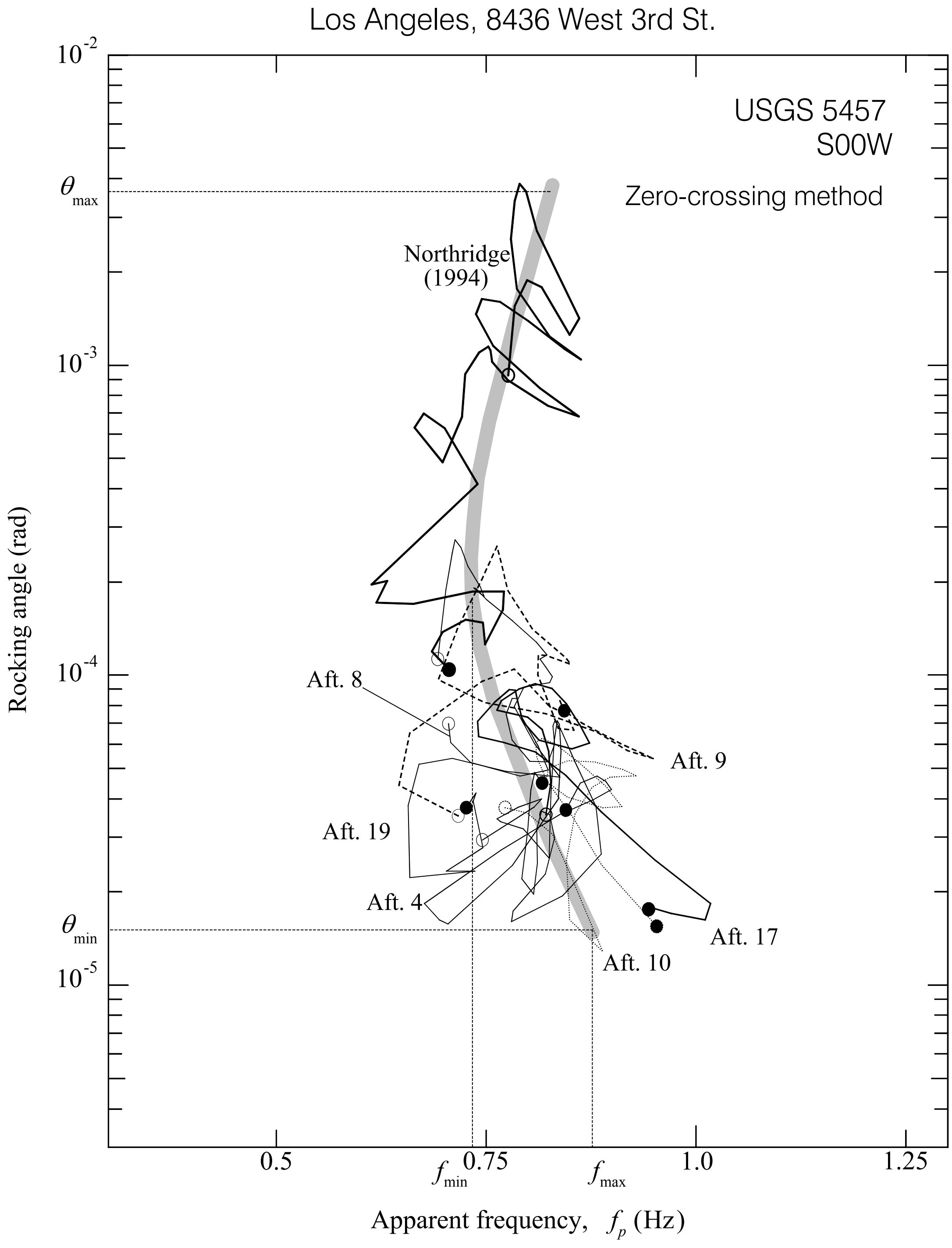


Figure 4.27 Instantaneous frequency versus amplitude of motion for station USGS 5457, for W00N vibrations, determined by the zero-crossing method, for several earthquakes.

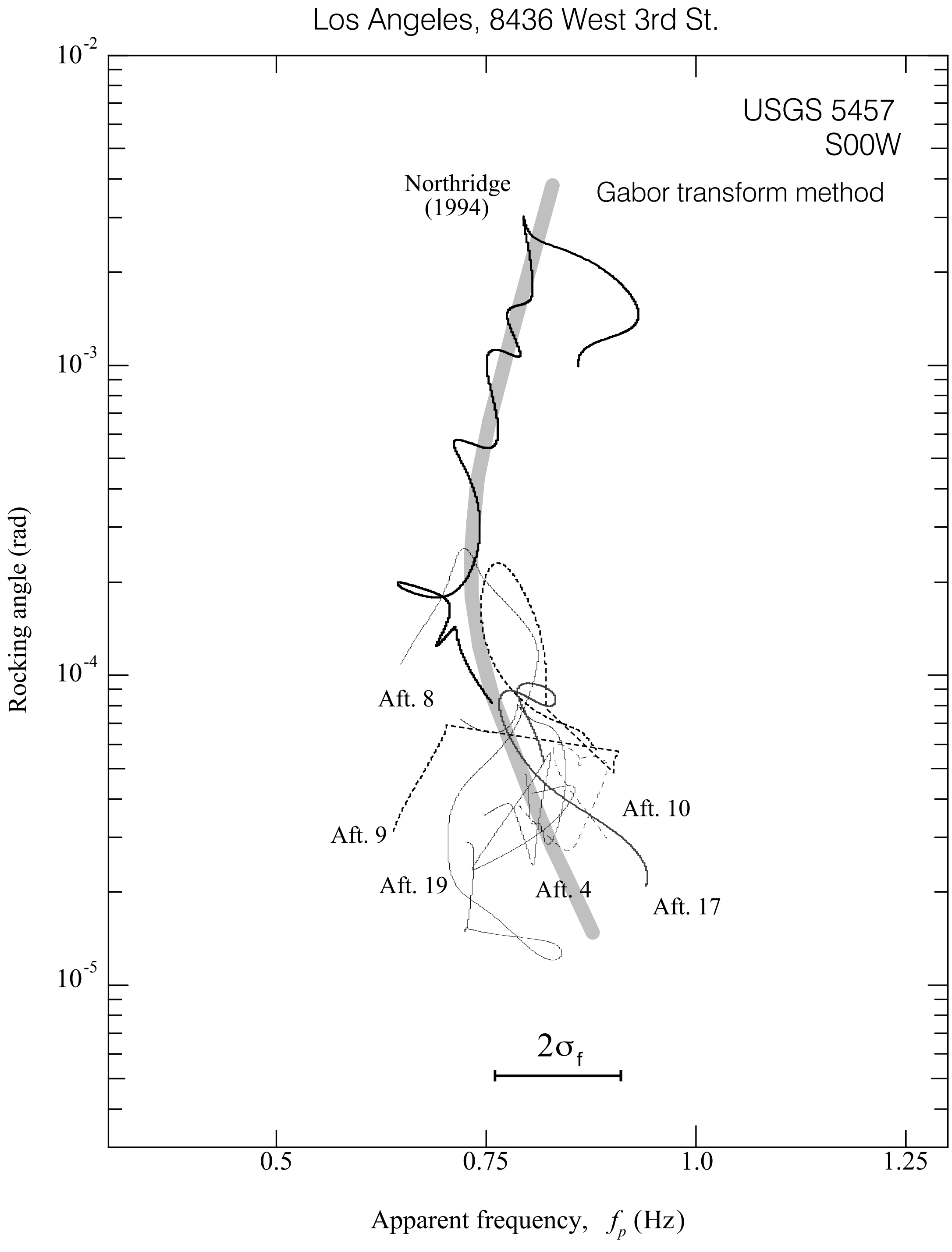


Figure 4.28 Instantaneous frequency versus amplitude of motion for station USGS 5457, for W00N vibrations, determined by the Gabor method, for several earthquakes.

Table 4.1 Maximum and minimum system frequencies and maximum and minimum rocking angles for seven instrumented buildings.

Station no.	Comp.	f_{max}, f_{min} (Hz)	$\Delta f / f_{max}$ (%)	θ_{max}, θ_{min} ($\times 10^{-3}$ rad)	Comp.	f_{max}, f_{min} (Hz)	$\Delta f / f_{max}$ (%)	θ_{max}, θ_{min} ($\times 10^{-3}$ rad)
5108	E00S	2.130, 1.648	22.64	0.49607, 0.00251	N00E	1.899, 1.525	19.68	1.05640, 0.00395
0466	N00E	0.377, 0.312	17.23	4.74628, 0.12339	W00N	0.295, 0.215	27.23	4.66436, 0.31591
5450	N00E	0.691, 0.614	11.16	3.08807, 0.03879	W00N	0.666, 0.576	13.52	5.16651, 0.03820
5451	N00E	0.329, 0.273	17.16	7.38386, 0.18001	W00N	0.434, 0.373	14.14	9.57349, 0.13386
5453	N00E	0.613, 0.434	29.20	7.87023, 0.06008	W00N	0.744, 0.712	5.69	4.88160, 0.02566
5455	E30S	0.434, 0.408	3.86	5.39350, 0.05552	N30E	0.425, 0.363	14.59	5.36059, 0.09933
5457	N00E	0.675, 0.569	15.76	6.34016, 0.02940	S00W	0.866, 0.704	18.62	3.62546, 0.01286

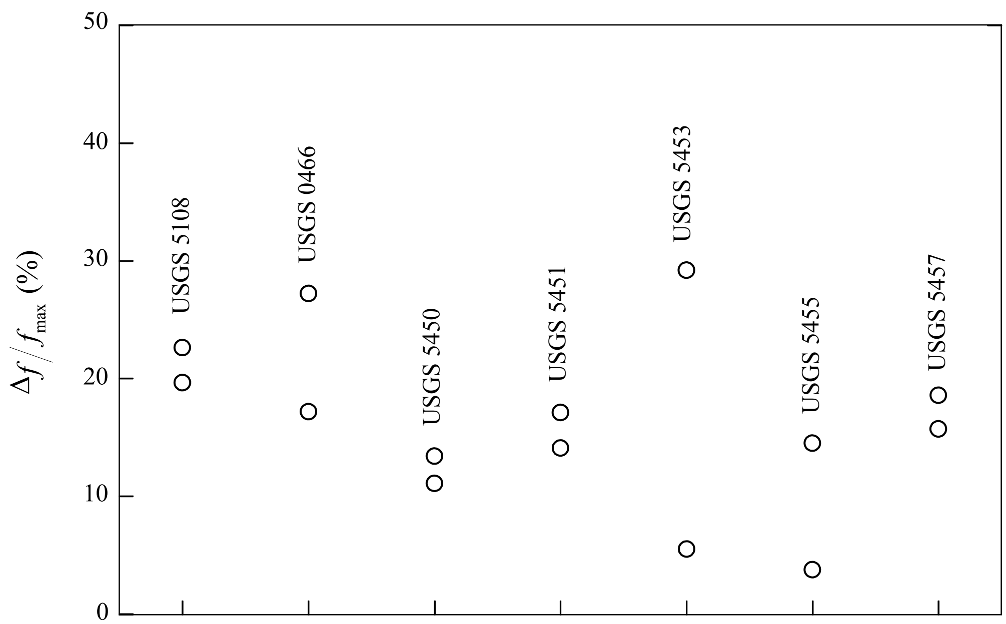


Figure 4.25 A summary of the changes of the building-soil system frequencies of the seven buildings analyzed in this report, determined from the observed trends during multiple earthquake excitations (see Figures 4.1 through 4.24). For each building, two values are shown, corresponding to the two horizontal components of motion. The change is expressed as a percentage of the maximum frequency.

5. SUMMARY AND CONCLUSIONS

This report presents new data of the response of seven buildings in the Los Angeles area to the 1994 Northridge earthquake and its aftershocks, which was digitized and processed for this project, and an analysis of the building-soil system frequency determined from these data. Although the number of recorded aftershocks in many of these buildings was large (up to about 80), only a small number of records were found to be useable for this analysis, because of the small signal to noise ratio at long periods which lead to high lower cut-off frequency, higher or too close to the system frequency. Data was initially processed for 15 other buildings, for which there are "good" film records of other earthquakes that should be added to the analysis. It is planned to complete the processing of the Northridge data, digitize and process the additional film records during a second phase of this project, for which funding is hoped to be secured.

The system frequency was estimated by two methods—zero crossing analysis, and from the ridge of the Gabor transform. The results by both methods are consistent. The general observed trend of the variation of the system frequency is decrease during the 1994 Northridge main event, and the 1971 San Fernando earthquake (one existing record of this earthquake was included in the analysis), which caused the largest amplitude response. However, for all but one building, the frequency was again larger during the aftershocks, indicating system recovery. For most buildings, the frequency changed up to 20%, and for two buildings, the change was about 30%. A permanent reduction of the frequency is consistent with permanent loss of stiffness, while a "recovery" to the initial higher value is consistent with the interpretation that the change was mainly due to changes in the soil (rather than in the structure itself), or changes in the bond between the soil and the foundation. A detailed analysis of the causes of these changes is beyond the scope of this project.

6. REFERENCES

1. Biot, M.A. (1942). "Analytical and experimented methods in engineering seismology," Trans., ASCE, 68, 365-409.
2. Carder, D.S. (1936). "Vibration observations," Chapter 5, in Earthquake Investigations in California 1934-1935, U.S. Dept. of Commerce, Coast and Geological Survey, Special Publication No. 201, Washington D.C.
3. Goel, R.K. and A.K. Chopra (1997). "Period formulas for concrete shear wall buildings," J. of Structural Eng., ASCE, 124(4), 426-433.
4. Hudson, D.E. (1970). "Dynamic tests of full scale structures," Chapter 7, 127-149, in Earthquake Engineering, Edited by R.L. Wiegel, Prentice Hall, N.J.
5. Lee, V.W. and M.D. Trifunac (1990). "Automatic digitization and processing of accelerograms using PC," Report No. 90-03, Dept. of Civil Engrg, U. of So. California, Los Angeles, CA.
6. Li, Y. and S.T. Mau (1979). "Learning from recorded earthquake motions in buildings," J. of Structural Engrg, ASCE, 123(1), 62-69.
7. Luco, J.E., M.D. Trifunac and H.L. Wong (1987). "On the apparent change in dynamic behavior of a nine story reinforced concrete building," Bull. Seism. Soc. Amer., 77(6), 1961-1983.
8. Stewart, J.P. R.B. Seed and G. L. Fenves (1999). "Seismic soil-structure interaction in buildings II: Empirical findings," J. of Geotechnical and Geoenvironmental Engrg, ASCE, 125(1), 38-48.
9. Todorovska, M.I. (1992). "Effect of the depth of the embedment on the system response during building-soil interaction," Soil Dynamics & Earthquake Engrg, 11 (2), 111-123.
10. Todorovska, M.I. (1993a). "In-plane foundation-soil interaction for embedded circular foundations," Soil Dynamics & Earthquake Engrg, 12 (5), 283-297.
11. Todorovska, M.I. (1993b). "Effects of the wave passage and the embedment depth during building-soil interaction," Soil Dynamics & Earthquake Engrg, 12 (6), 343-355.
12. Todorovska, M.I. (1995). "A note on distribution of amplitudes of peaks in structural response including uncertainties of the exciting ground motion and of the structural model," Soil Dynamics & Earthquake Engrg, 14 (3), 211-217.
13. Todorovska, M.I. (2001). "Estimation of instantaneous frequency of signals using the continuous wavelet transform," Report CE 01-07, Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, California.
14. Todorovska, M.I., & M.D. Trifunac (1992). "The system damping, the system frequency and the system response peak amplitudes during in-plane building-soil interaction," Earthquake Engrg & Struct. Dynamics, 21 (2), 127-144.
15. Todorovska, M.I., & M.D. Trifunac (1993). "The effects of the wave passage on the response of base-isolated buildings on rigid embedded foundations," Rep. No. CE 93-10, Dept. of Civil Engrg, Univ. of Southern California, Los Angeles, California, pp. 231.
16. Todorovska, M.I., A. Hayir & M.D. Trifunac (2001). "Flexible versus rigid foundation models of soil-structure interaction: incident SH-waves," Proc. 2nd U.S.-Japan Workshop on Soil-Structure Interaction, March 6-8, 2001, Tsukuba City, Japan, pp. 19.
17. Todorovska, M.I., M.D. Trifunac, V.W. Lee, C.D. Stephens, K.A. Fogleman, C. Davis and R. Tognazzini (1999). "The ML = 6.4 Northridge, California, Earthquake and Five M > 5 Aftershocks

Between 17 January and 20 March 1994 - Summary of Processed Strong Motion Data," Report CE 99-01, Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, California.

18. Trifunac, M.D., V.W. Lee and M.I. Todorovska (1999). "Common problems in automatic digitization of accelerograms," Soil Dynamics and Earthquake Engineering, (submitted for publication).

19. Trifunac, M.D., & M.I. Todorovska (1998). "Relative flexibility of a building foundation," Proc. US-Japan Workshop on Soil-Structure Interaction, Menlo Park, California, 20-23 Sept., 1998, pp. 20.

20. Trifunac, M.D. and M.I. Todorovska (1998). "Nonlinear soil response as a natural passive isolation mechanism–the 1994 Northridge, California, earthquake," Soil Dynamics and Earthquake Engrg, 17(1), 41-51.

21. Trifunac, M.D., T.Y. Hao & M.I. Todorovska (2001a). "On energy flow in earthquake response," Report CE 01-03, Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, California.

22. Trifunac, M.D., T.Y. Hao & M.I. Todorovska (2001b). "Energy of earthquake response as a design tool," Proc. 13th Mexican National Conf. on Earthquake Engineering, Guadalajara, Mexico.

23. Trifunac, M.D., M.I. Todorovska and T.Y. Hao (2001c). "Full-scale experimental studies of soil-structure interaction - a review," Proc. 2nd U.S.-Japan Workshop on Soil-Structure Interaction, March 6-8, 2001, Tsukuba City, Japan, pp. 52.

24. Udwadia, F.E. and M.D. Trifunac (1974). "Time and Amplitude Dependent Response of Structures," Earthquake Engrg and Structural Dynamics, 2, 359-378.

Appendix A.0466

LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th Floor)

Table A.0466.1 List of processed records

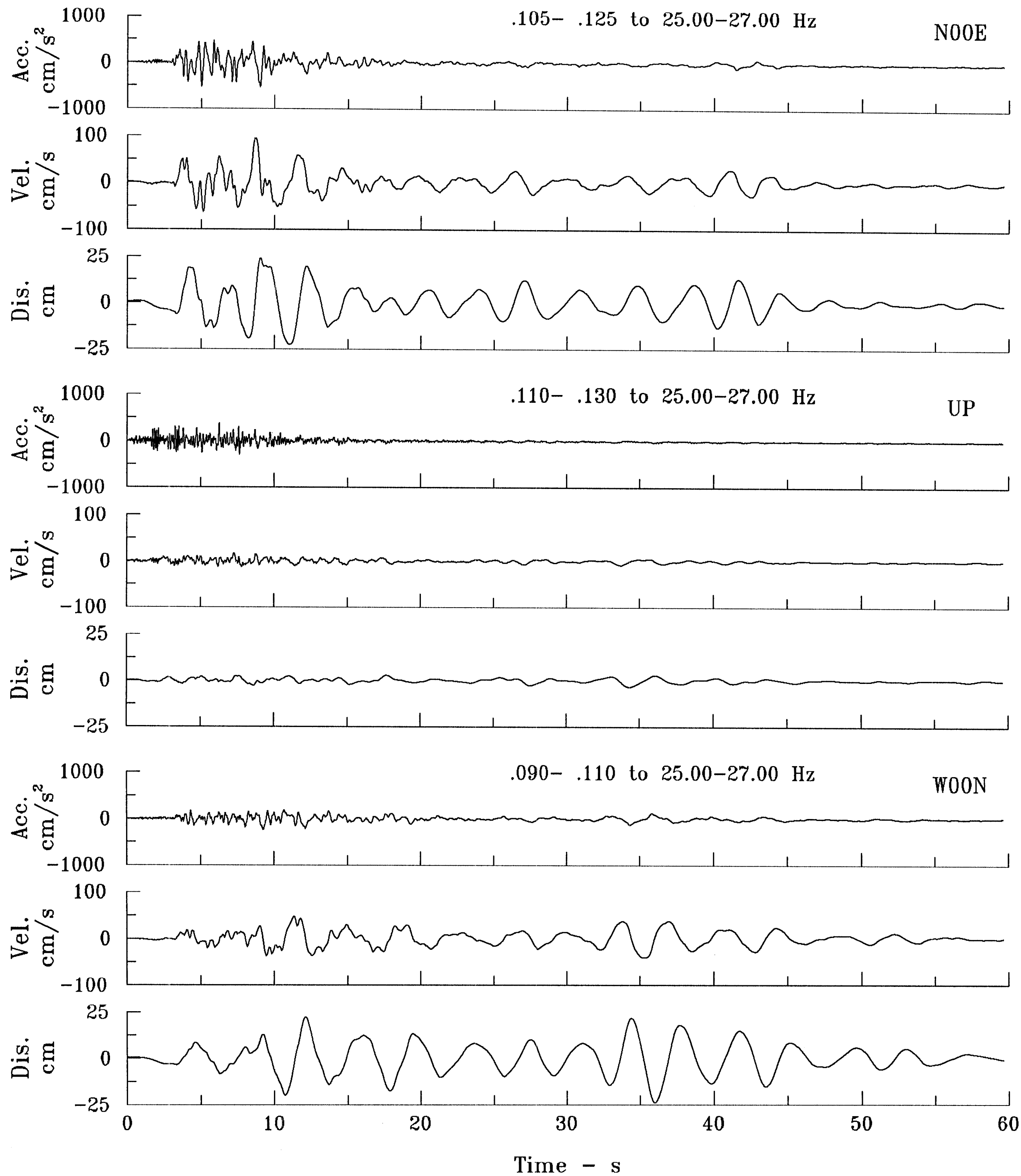
USGS: 0466 SMA-1 185	LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th floor)					34.157°N 117.476°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp.	Peak Acc. [g]
v1x0000.dat	IAA000	94.000.0	NORTHRIDGE EARTHQUAKE	9.0	59.7	N00E	0.550
						UP	0.394
						W00N	0.257
v1x0001.dat	IAA001	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	15.9	33.2	N00E	0.151
						UP	0.097
						W00N	0.054

STATION USGS 466 34.157 N, 118.476 W SMA-1 185

LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 8.58 KM

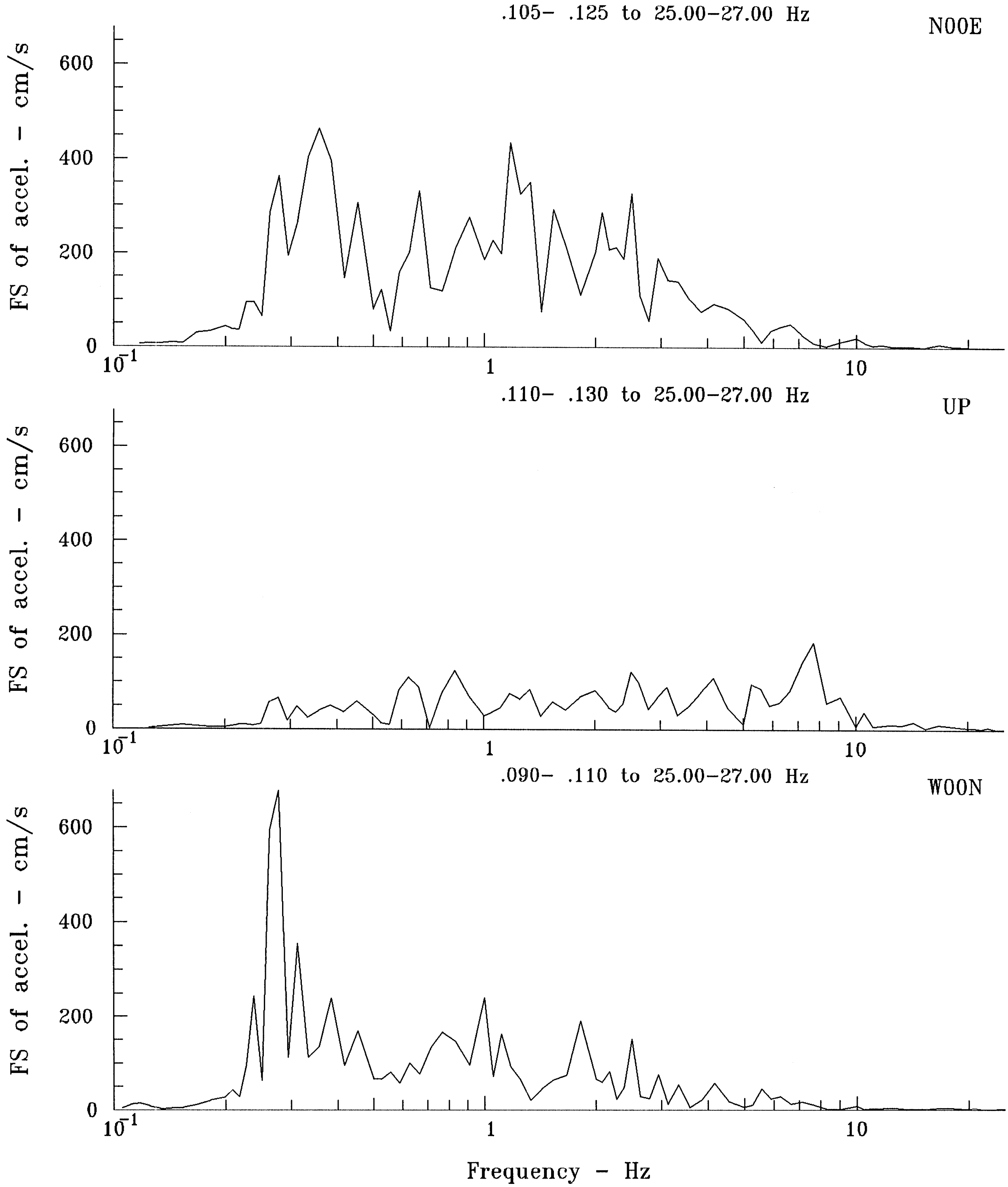


STATION USGS 466 34.157 N, 118.476 W SMA-1 185

LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 8.58 KM

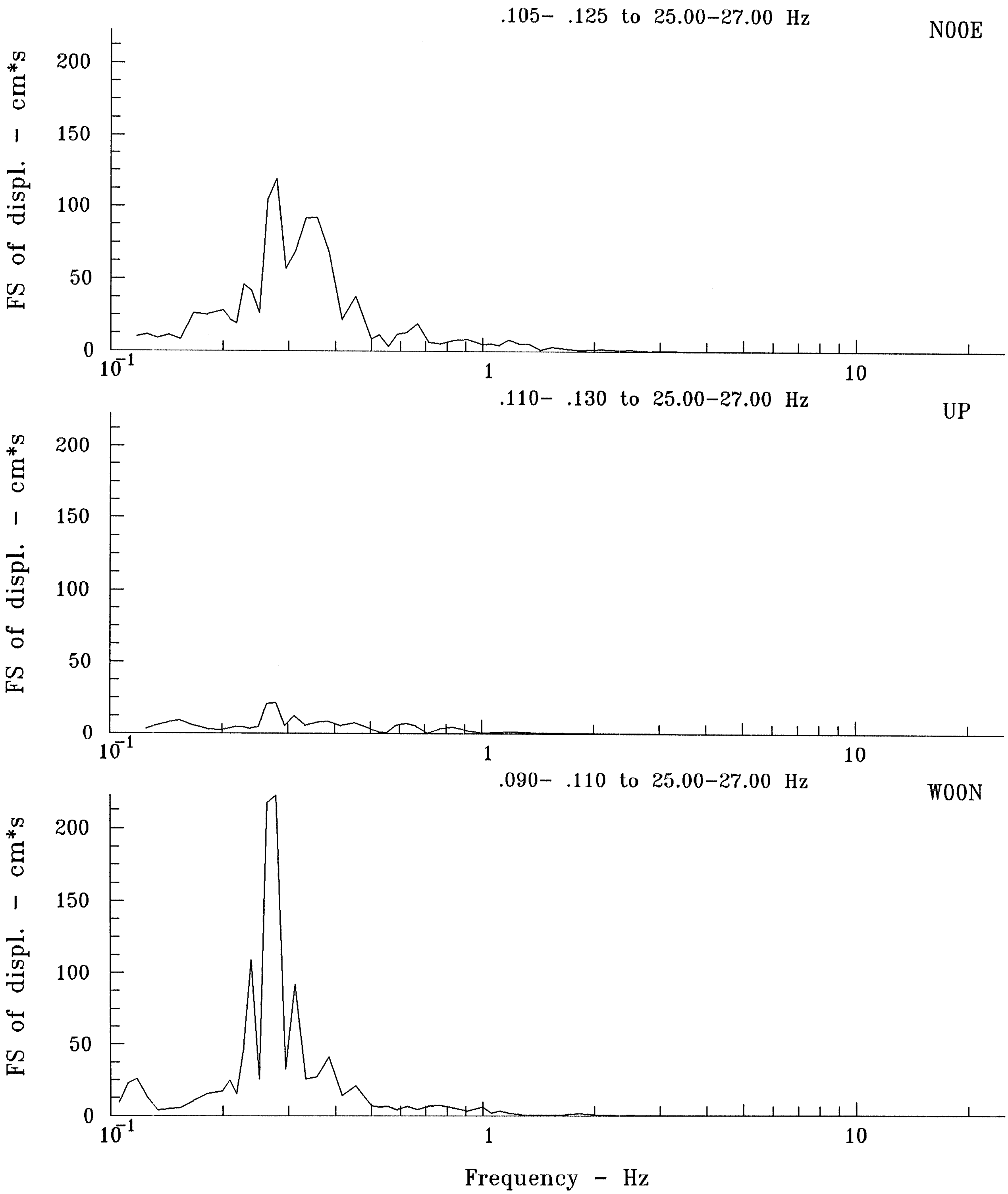


STATION USGS 466 34.157 N, 118.476 W SMA-1 185

LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 8.58 KM

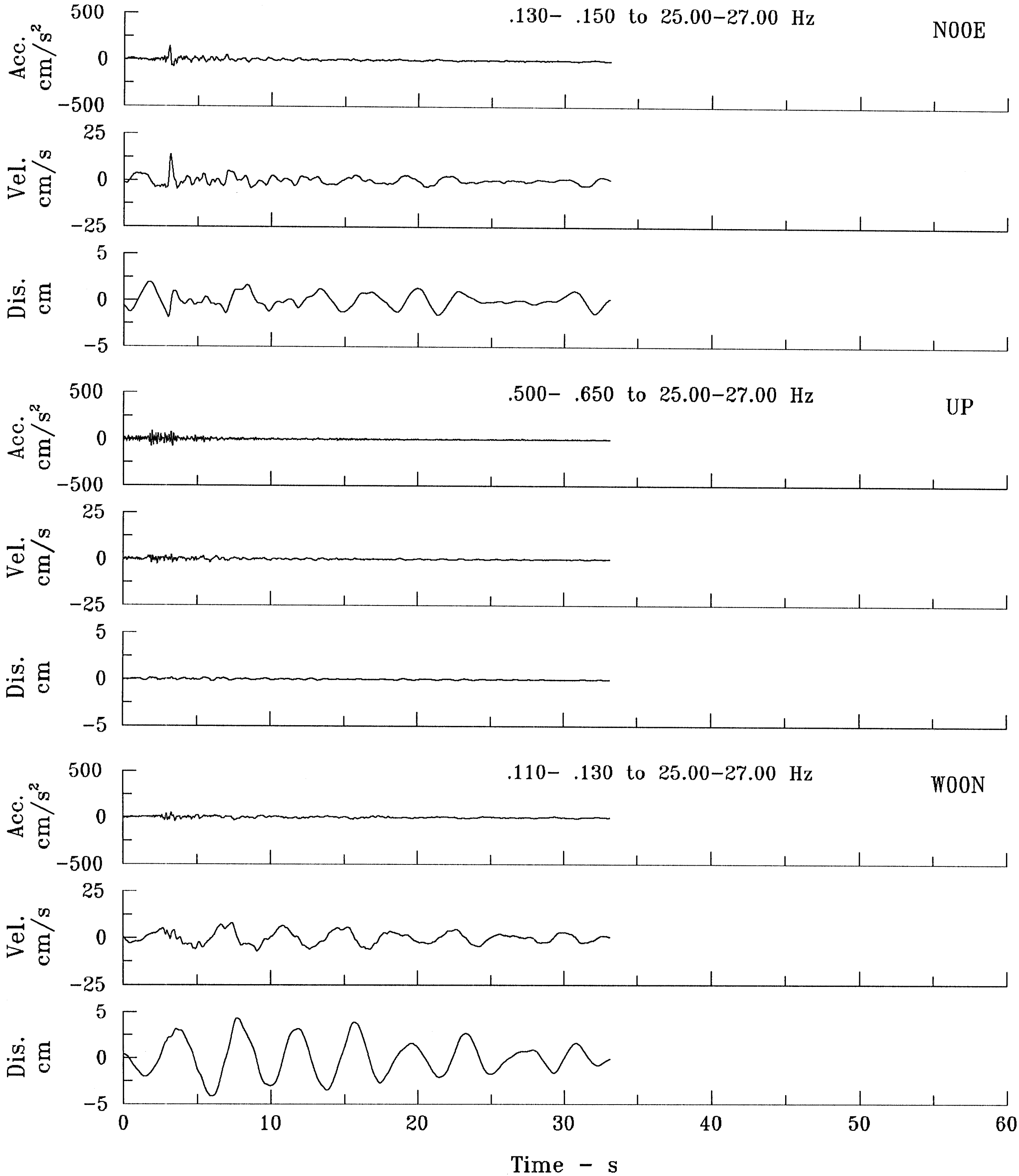


STATION USGS 466 34.157 N, 118.476 W SMA-1 185

LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.95 KM

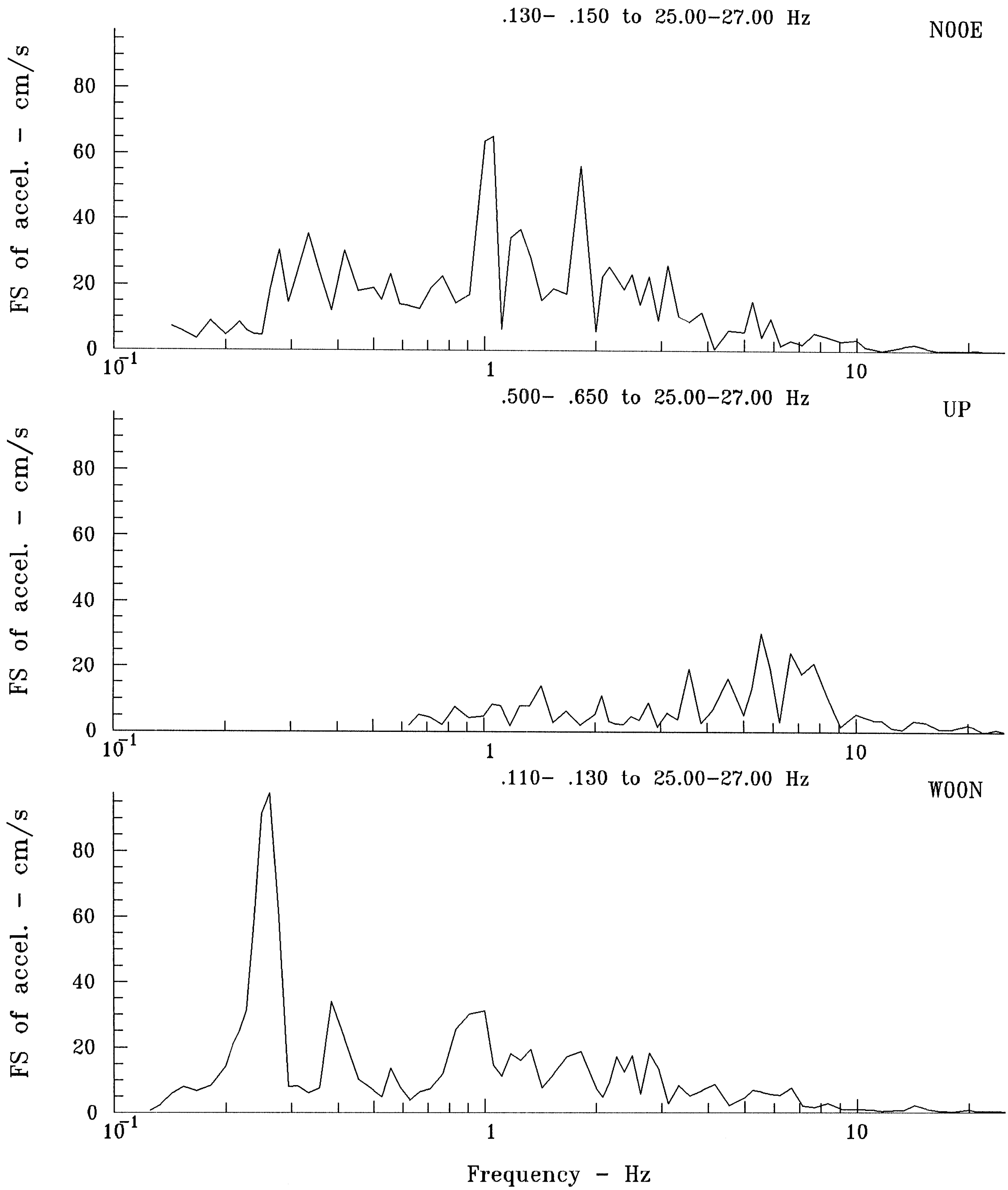


STATION USGS 466 34.157 N, 118.476 W SMA-1 185

LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.95 KM

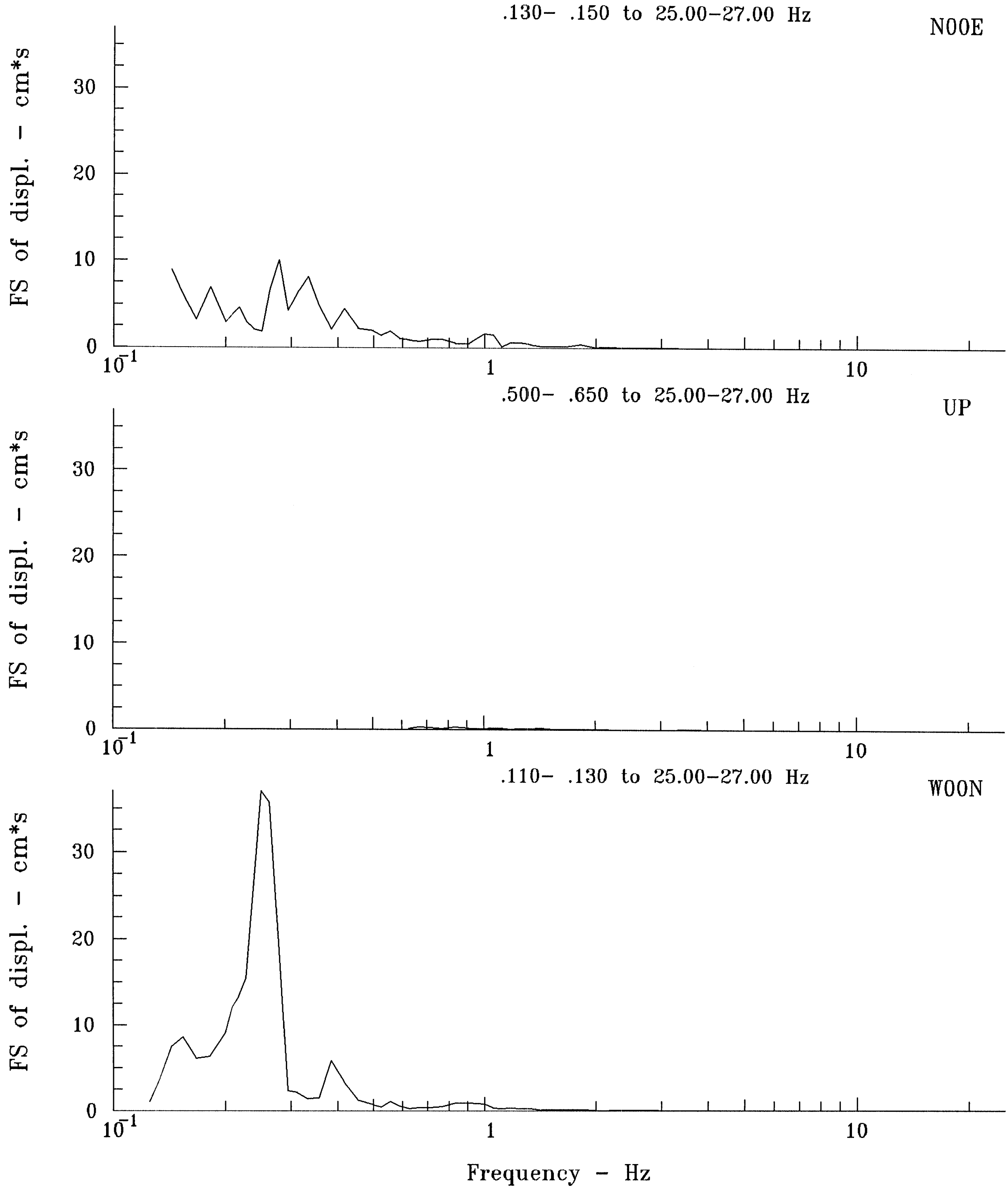


STATION USGS 466 34.157 N, 118.476 W SMA-1 185

LOS ANGELES, 15250 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.95 KM



Appendix A.5108

SANTA SUSANA, ETEC Bldg 462

Table A.5108.1 List of processed records — 6th floor

USGS: 5108 SMA 1276	SANTA SUSANA, ETEC Bldg 462 (6th Floor)					34.230°N 118.712°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp.	Peak Acc. [g]
V1X8900.dat	IAA001	94.890.0	NORTHRIDGE EARTHQUAKE	16.3	59.8	E00S	0.392
						UP	0.398
						N00E	0.595
V1X8901.dat	IAA002	94.890.1	NORTHRIDGE EARTHQUAKE (aft. 7)	16.8	34.2	E00S	0.019
						UP	0.018
						N00E	0.019
V1X8902.dat	IAA003	94.890.2	NORTHRIDGE EARTHQUAKE (aft. 9)	16.1	43.1	E00S	0.032
						UP	0.040
						N00E	0.045
V1X8904.dat	IAA005	94.890.4	NORTHRIDGE EARTHQUAKE (aft. 100)	12.9	37.6	E00S	0.039
						UP	0.027
						N00E	0.025
V1X8905.dat	IAA006	94.890.5	NORTHRIDGE EARTHQUAKE (aft. 129)	15.7	42.8	E00S	0.165
						UP	0.106
						N00E	0.127
V1X8906.dat	IAA007	94.890.6	NORTHRIDGE EARTHQUAKE (aft. 142)	10.9	46.0	E00S	0.129
						UP	0.071
						N00E	0.075
V1X8907.dat	IAA008	94.890.7	NORTHRIDGE EARTHQUAKE (aft. 151)	16.4	34.9	E00S	0.021
						UP	0.017
						N00E	0.035
V1X8908.dat	IAA009	94.890.8	NORTHRIDGE EARTHQUAKE (aft. 253)	16.5	43.1	E00S	0.089
						UP	0.051
						N00E	0.046
V1X8909.dat	IAA010	94.890.9	NORTHRIDGE EARTHQUAKE (aft. 254)	18.5	43.9	E00S	0.034
						UP	0.031
						N00E	0.025
V1X8910.dat	IAA011	94.891.0	NORTHRIDGE EARTHQUAKE (aft. 336)	14.9	42.7	E00S	0.089
						UP	0.074
						N00E	0.070
V1X8911.dat	IAA012	94.891.1	NORTHRIDGE EARTHQUAKE (aft. 392)	16.5	41.8	E00S	0.043
						UP	0.037
						N00E	0.038

Table A.5108.2 List of processed records — 1st floor

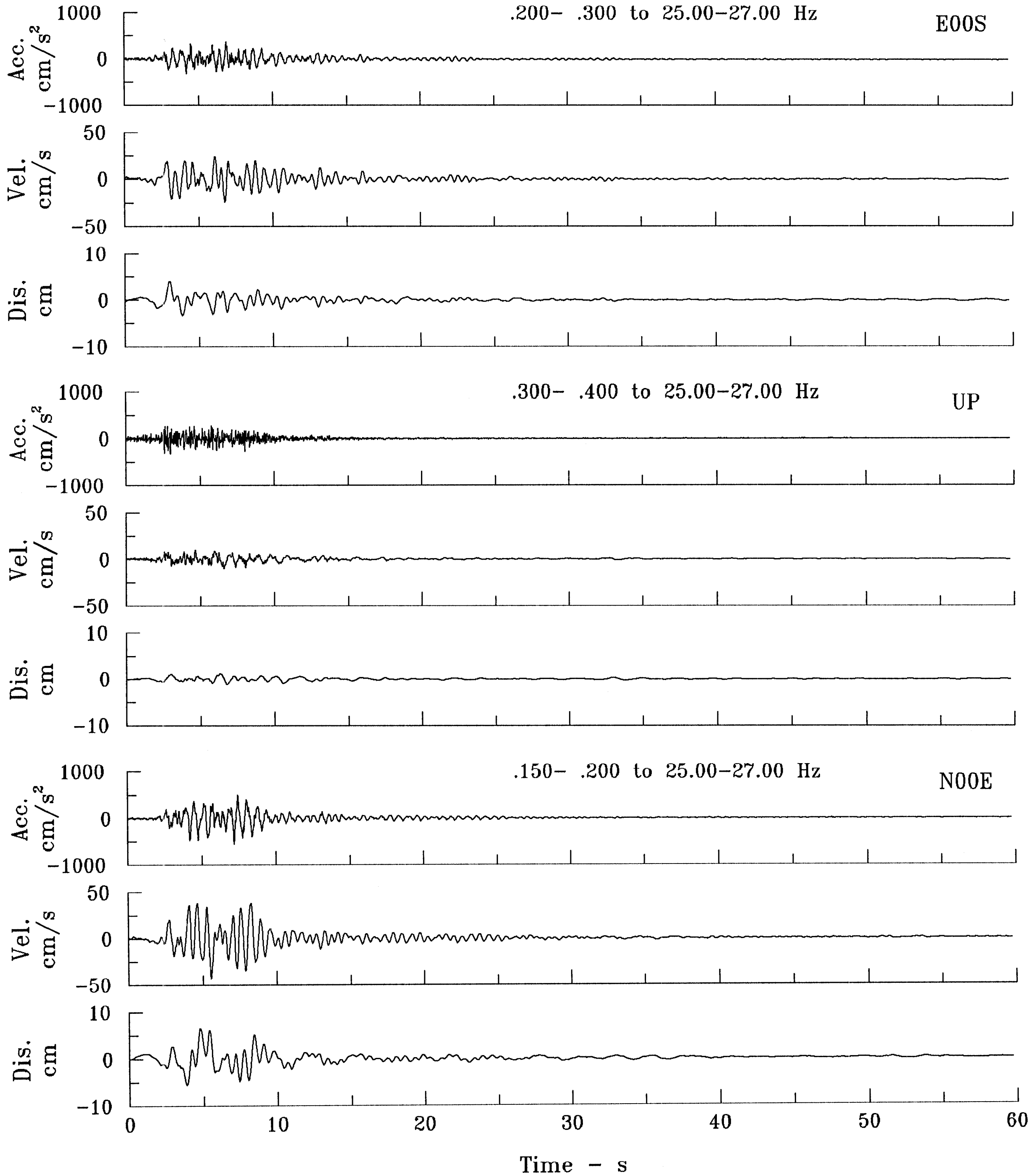
USGS: 5108 SMA 1277	SANTA SUSANA, ETEC Bldg 462 (1st Floor)					34.230°N 118.712°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp.	Peak Acc. [g]
V1X0300.dat	IAA013	94.030.0	NORTHRIDGE EARTHQUAKE	16.3	60.1	E00S	0.236
						UP	0.226
						N00E	0.335
V1X0301.dat	IAA014	94.030.1	NORTHRIDGE EARTHQUAKE (aft. 7)	16.8	34.2	E00S	0.023
						UP	0.010
						N00E	0.022
V1X0302.dat	IAA015	94.030.2	NORTHRIDGE EARTHQUAKE (aft. 9)	16.1	43.1	E00S	0.037
						UP	0.019
						N00E	0.032
V1X0304.dat	IAA018	94.030.4	NORTHRIDGE EARTHQUAKE (aft. 100)	12.9	37.6	E00S	0.030
						UP	0.015
						N00E	0.023
V1X0305.dat	IAA019	94.030.5	NORTHRIDGE EARTHQUAKE (aft. 129)	15.7	42.8	E00S	0.151
						UP	0.045
						N00E	0.181
V1X0306.dat	IAA020	94.030.6	NORTHRIDGE EARTHQUAKE (aft. 142)	10.9	46.5	E00S	0.043
						UP	0.047
						N00E	0.061
V1X0307.dat	IAA021	94.030.7	NORTHRIDGE EARTHQUAKE (aft. 151)	16.4	31.8	E00S	0.016
						UP	0.010
						N00E	0.024
V1X0308.dat	IAA022	94.030.8	NORTHRIDGE EARTHQUAKE (aft. 253)	16.5	43.1	E00S	0.036
						UP	0.024
						N00E	0.039
V1X0309.dat	IAA023	94.030.9	NORTHRIDGE EARTHQUAKE (aft. 254)	18.5	43.9	E00S	0.027
						UP	0.016
						N00E	0.021
V1X0310.dat	IAA024	94.031.0	NORTHRIDGE EARTHQUAKE (aft. 336)	14.9	42.7	E00S	0.096
						UP	0.036
						N00E	0.090
V1X0311.dat	IAA025	94.031.1	NORTHRIDGE EARTHQUAKE (aft. 392)	16.5	41.8	E00S	0.047
						UP	0.021
						N00E	0.047

STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 16.32 KM

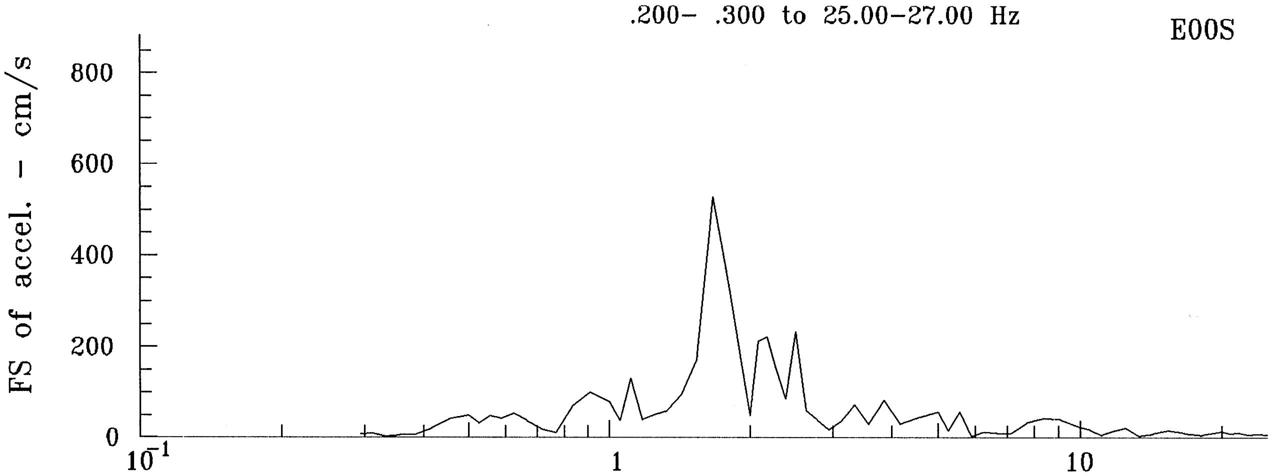


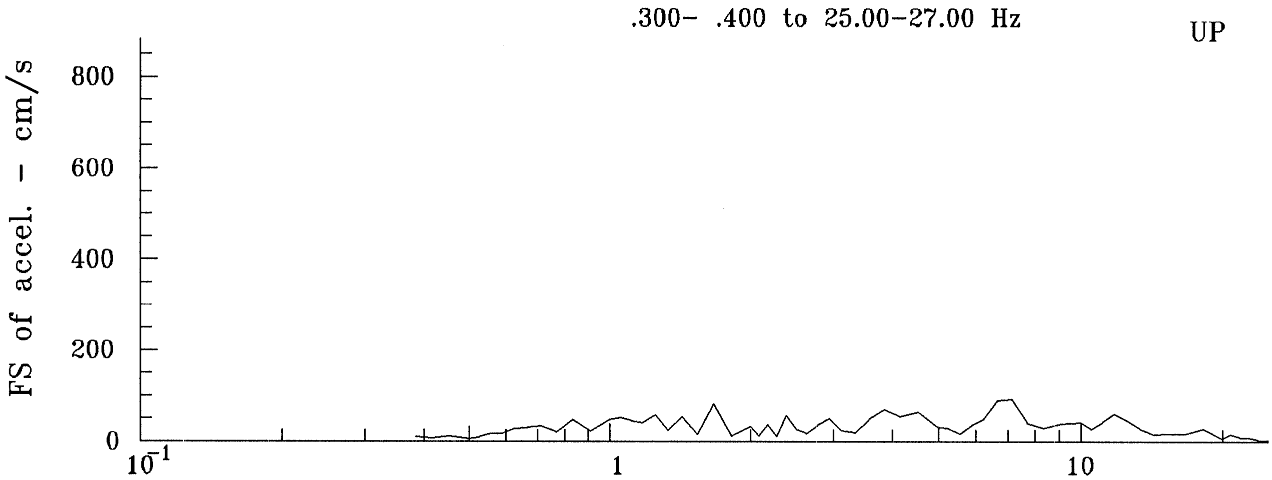
STATION USGS 5108 34.230 N, 118.712 W SER # 1276

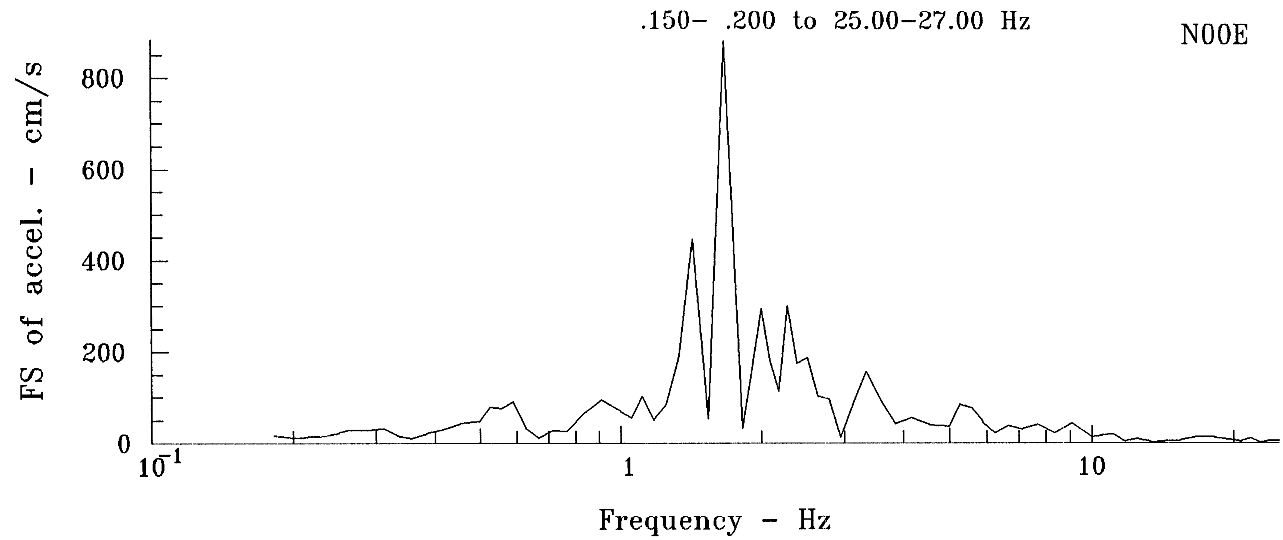
SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 16.32 KM





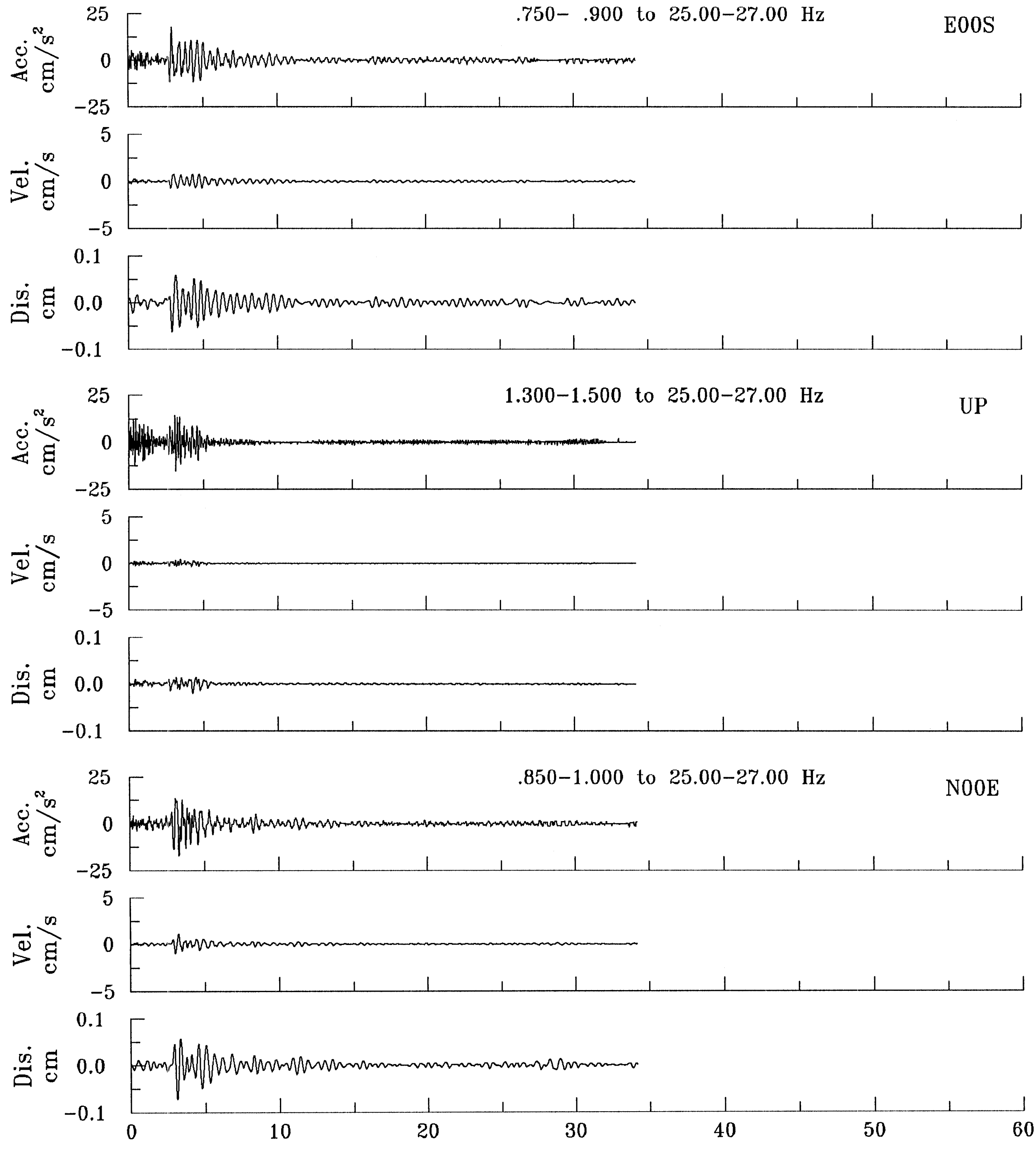


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 7) JAN 17, 1994 -1239 GMT

MAGNITUDE = 4.9 EPICENTRAL DISTANCE = 16.80 KM

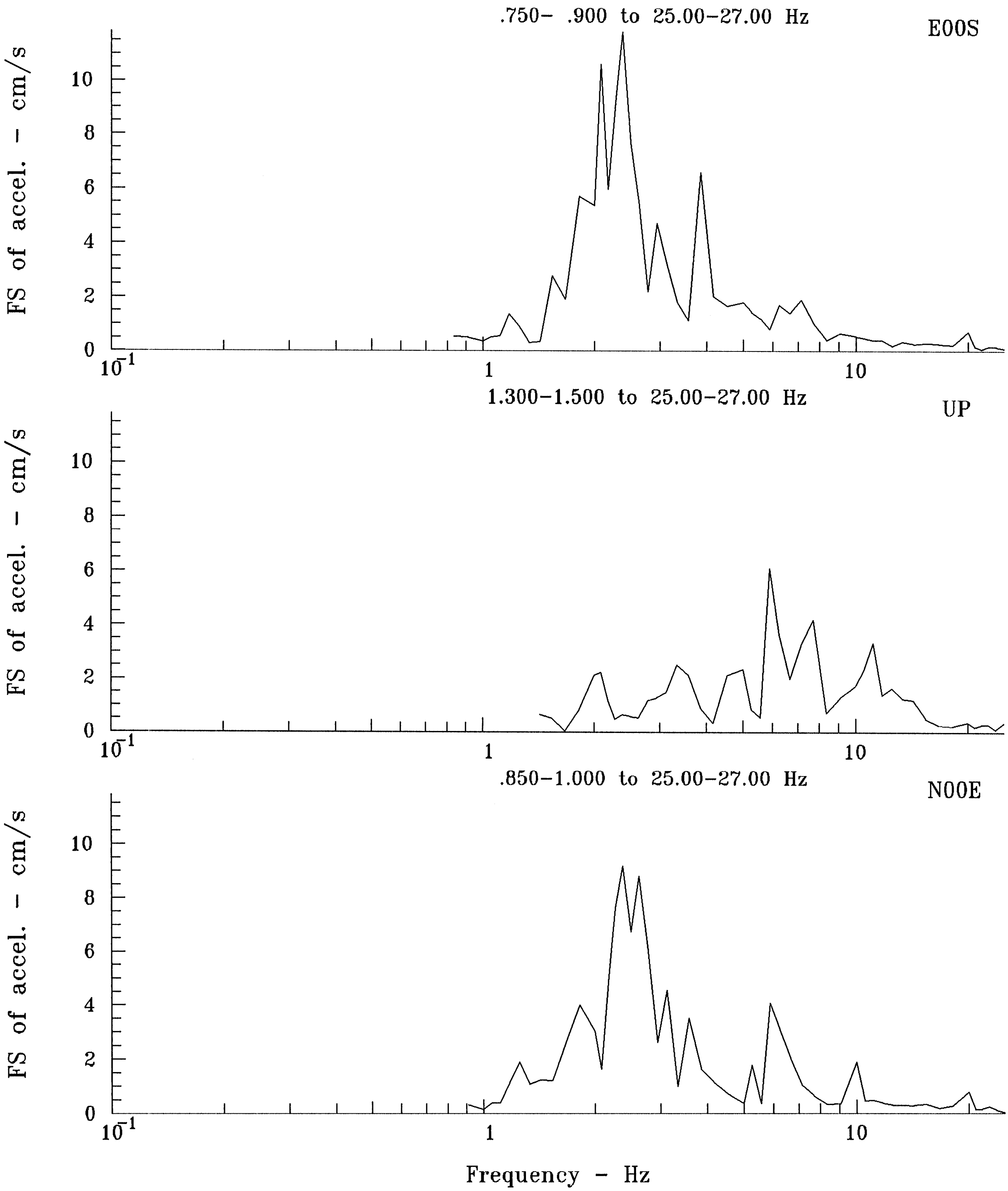


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 7) JAN 17, 1994 -1239 GMT

MAGNITUDE = 4.9 EPICENTRAL DISTANCE = 16.80 KM

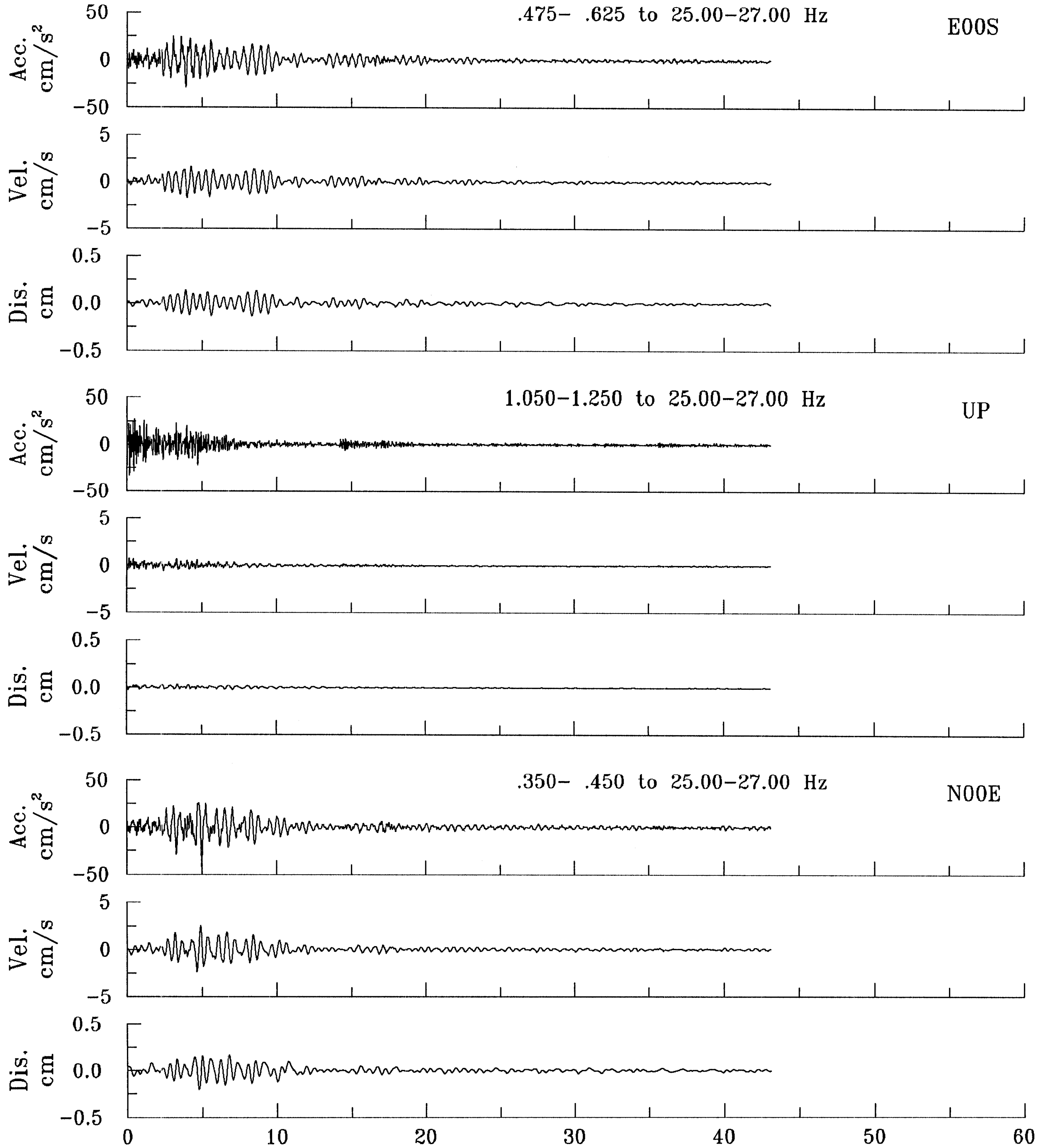


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 9) JAN 17, 1994 -1240 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 16.12 KM

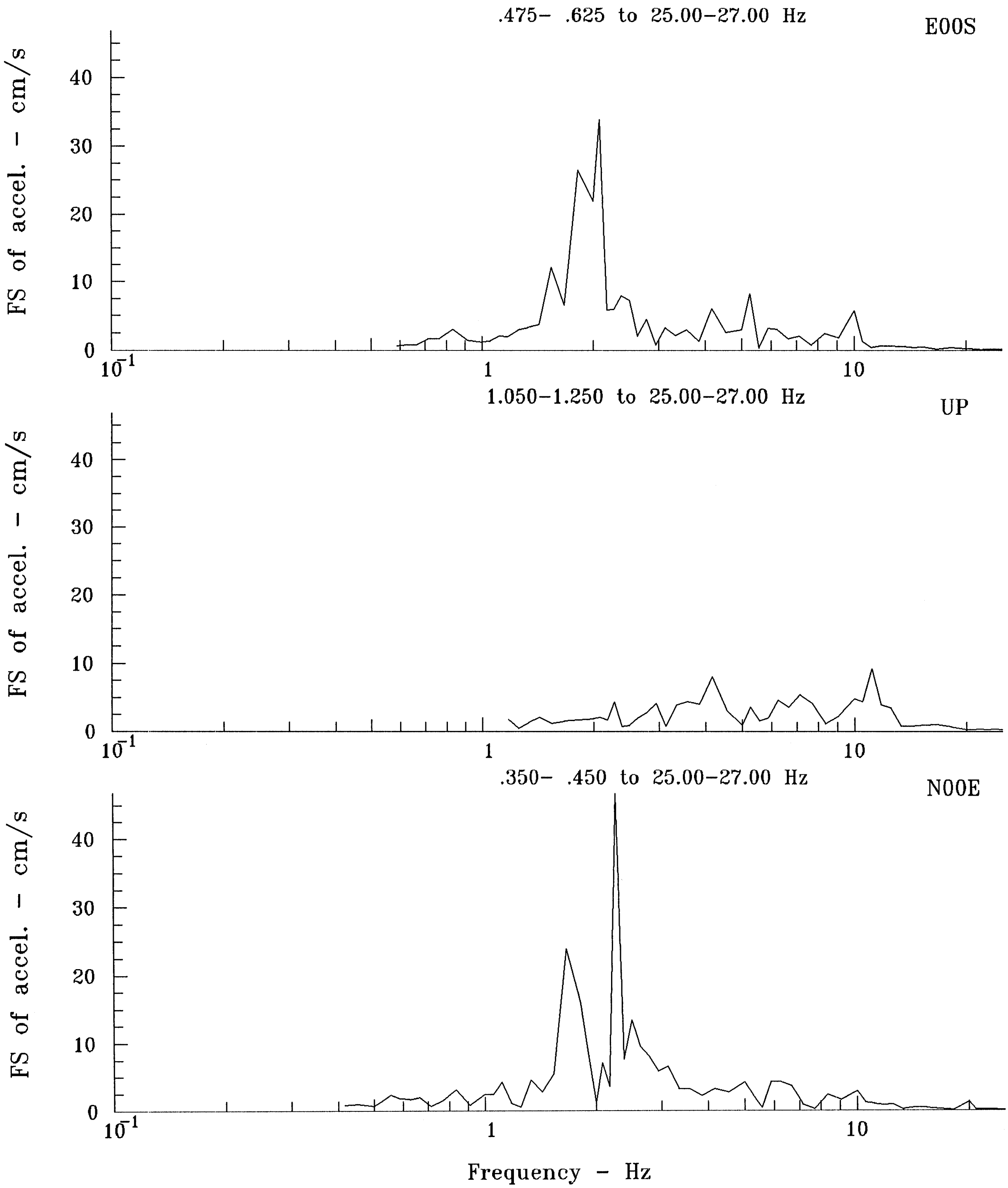


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 9) JAN 17, 1994 -1240 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 16.12 KM

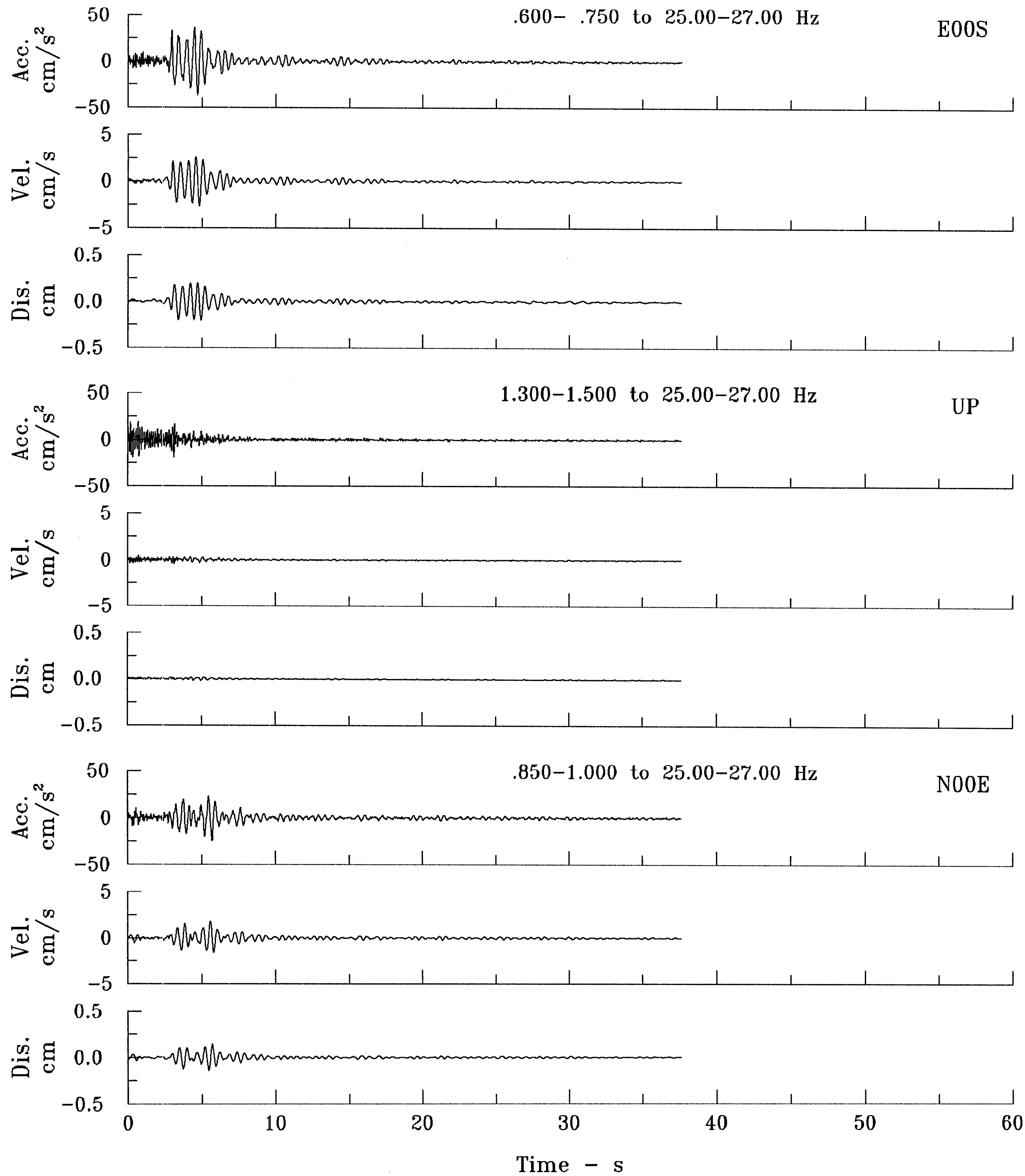


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 100) JAN 17, 1994 -1756 GMT

MAGNITUDE = 4.6 EPICENTRAL DISTANCE = 12.89 KM

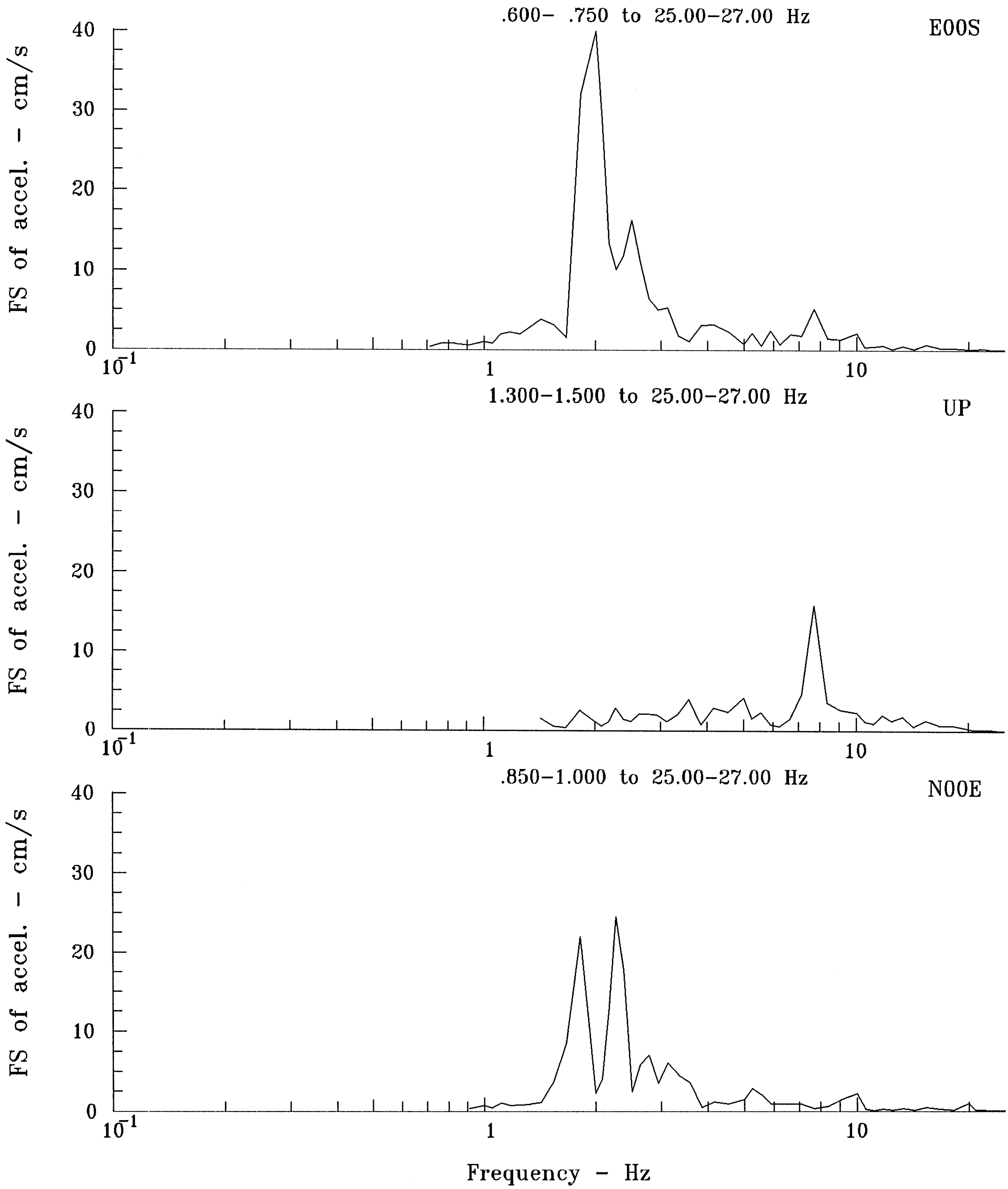


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 100) JAN 17, 1994 -1756 GMT

MAGNITUDE = 4.6 EPICENTRAL DISTANCE = 12.89 KM

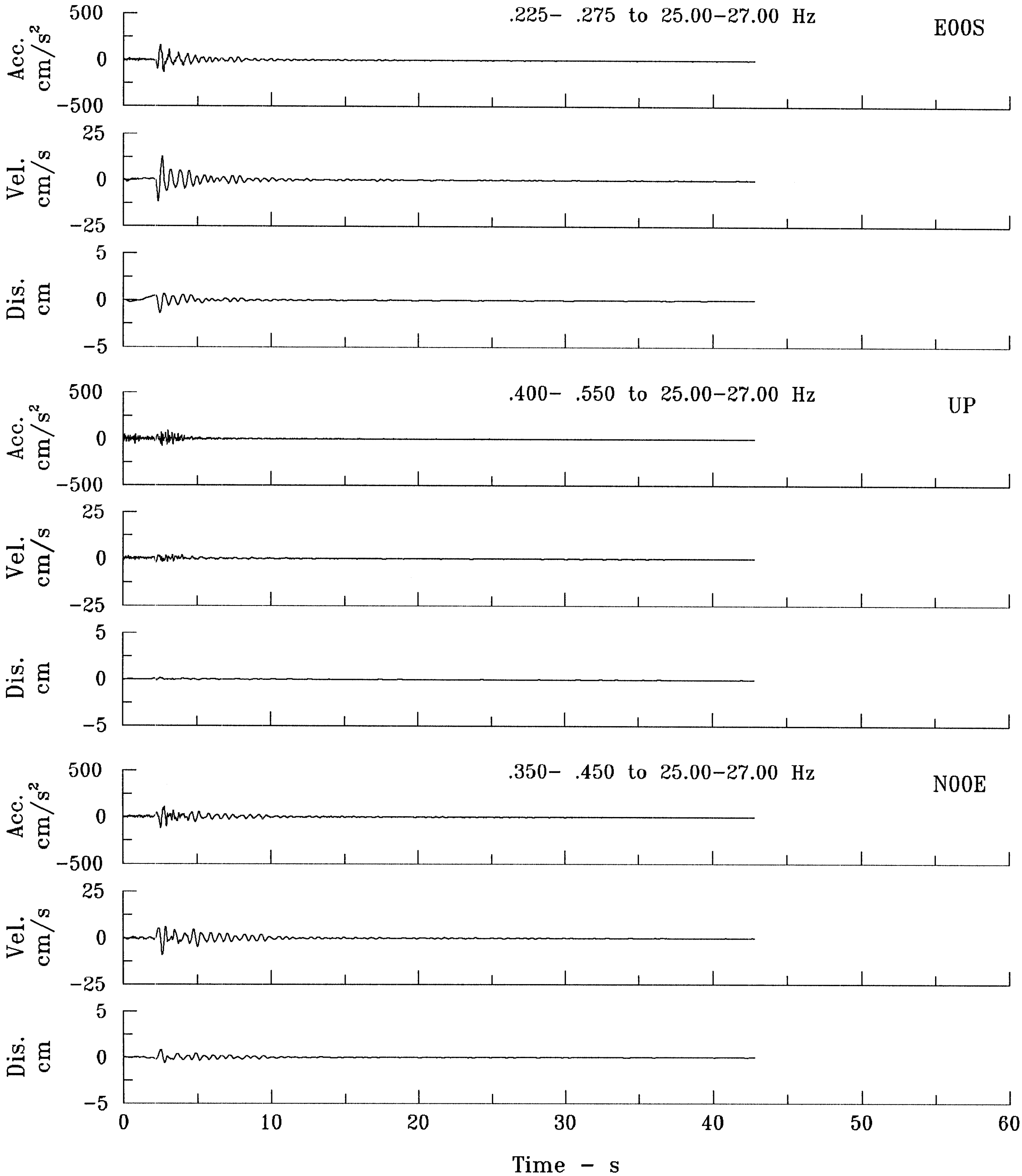


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 129) JAN 17, 1994 -2046 GMT

MAGNITUDE = 4.9 EPICENTRAL DISTANCE = 15.73 KM

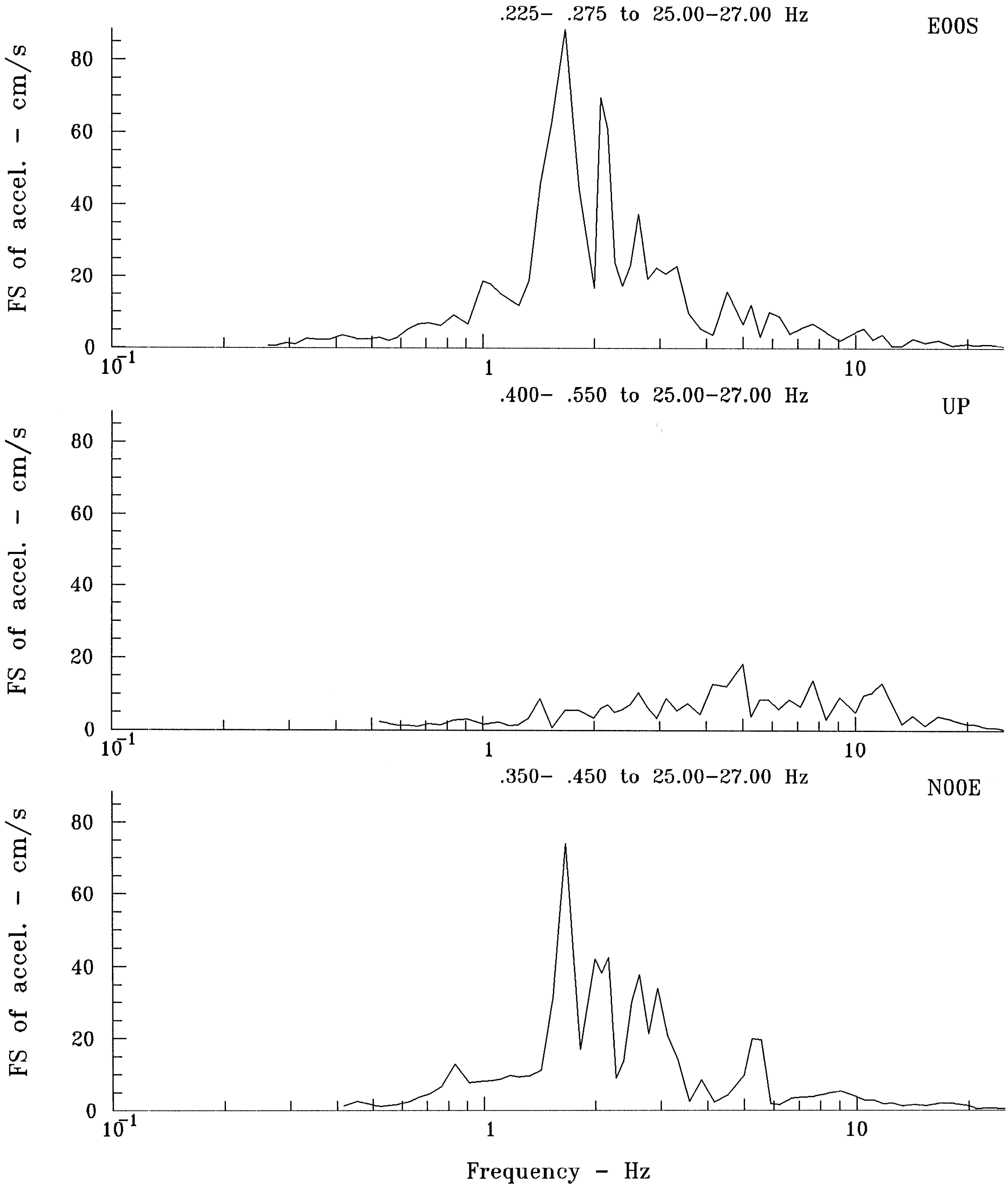


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 129) JAN 17, 1994 -2046 GMT

MAGNITUDE = 4.9 EPICENTRAL DISTANCE = 15.73 KM

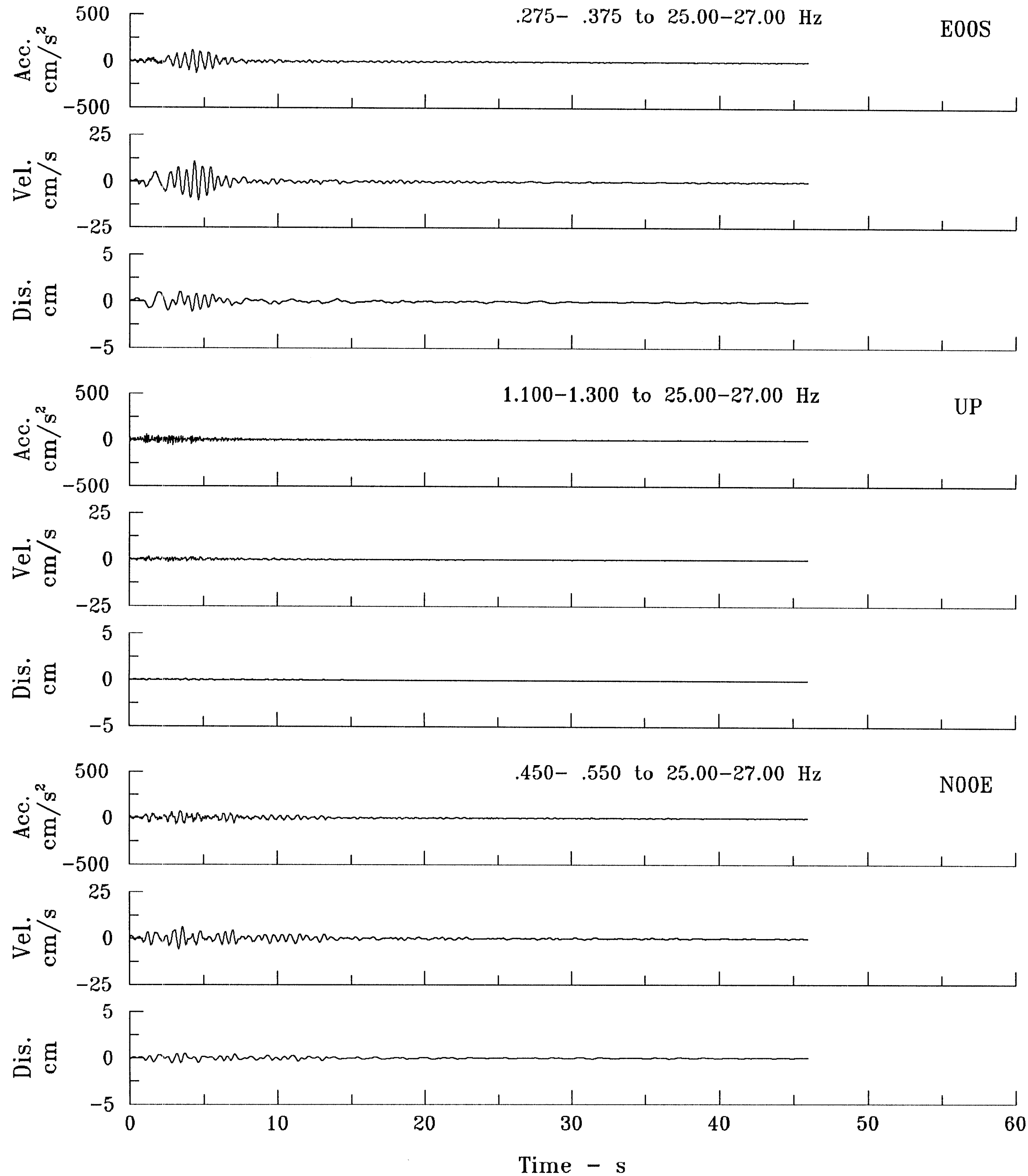


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 142) JAN 17, 1994 -2333 GMT

MAGNITUDE = 5.6 EPICENTRAL DISTANCE = 10.87 KM

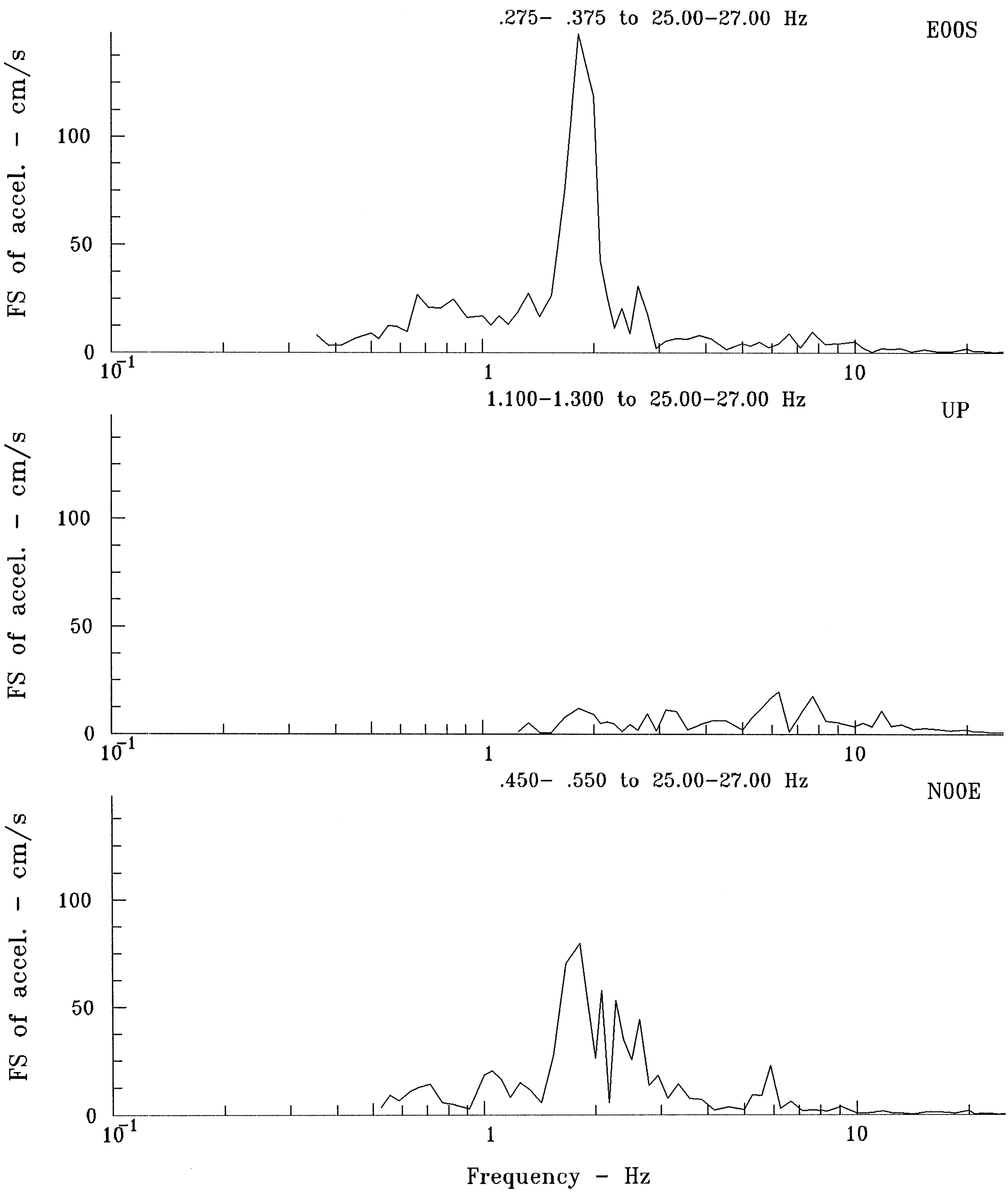


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 142) JAN 17, 1994 -2333 GMT

MAGNITUDE = 5.6 EPICENTRAL DISTANCE = 10.87 KM

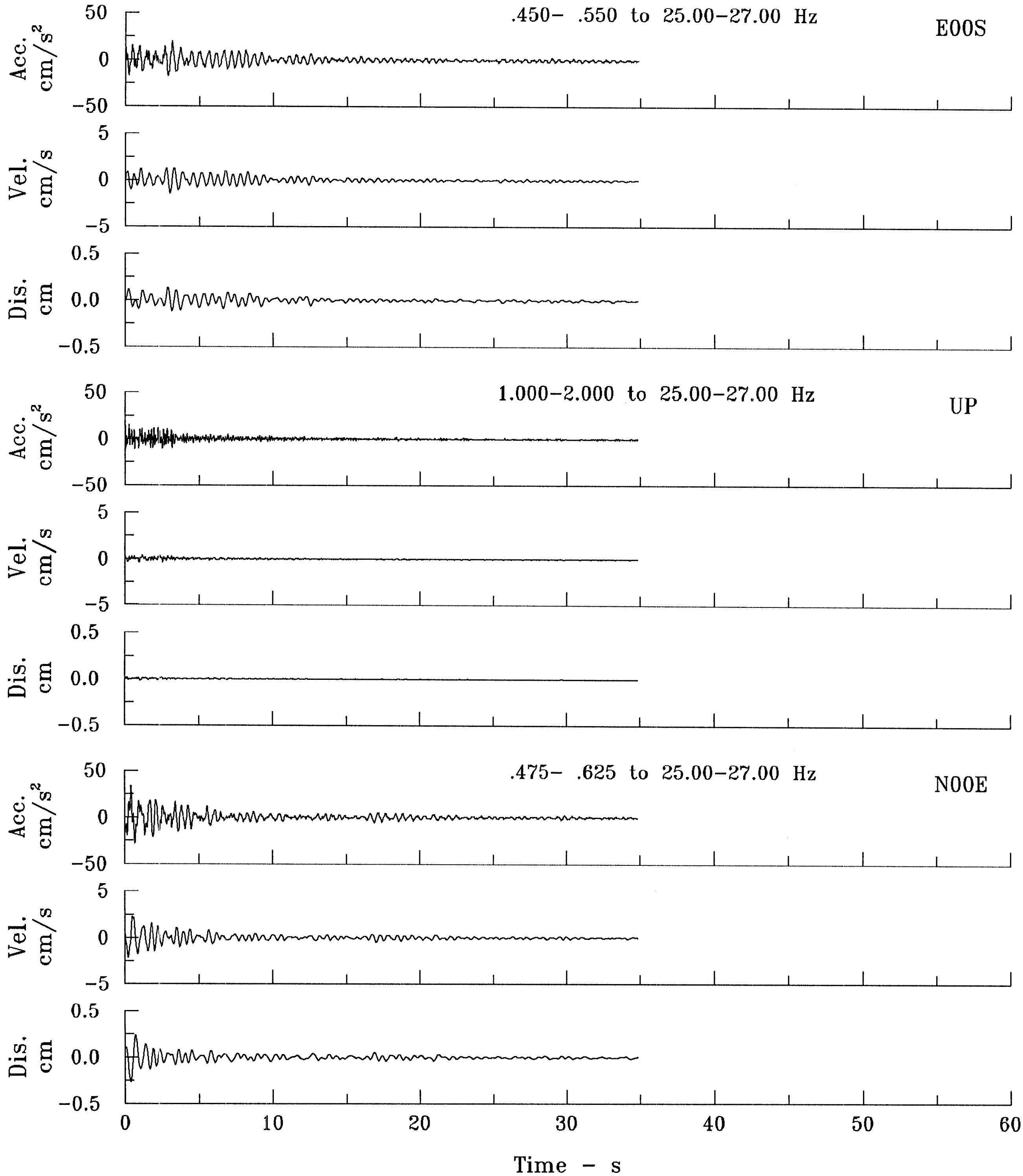


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 151) JAN 18, 1994 -0043 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 16.36 KM

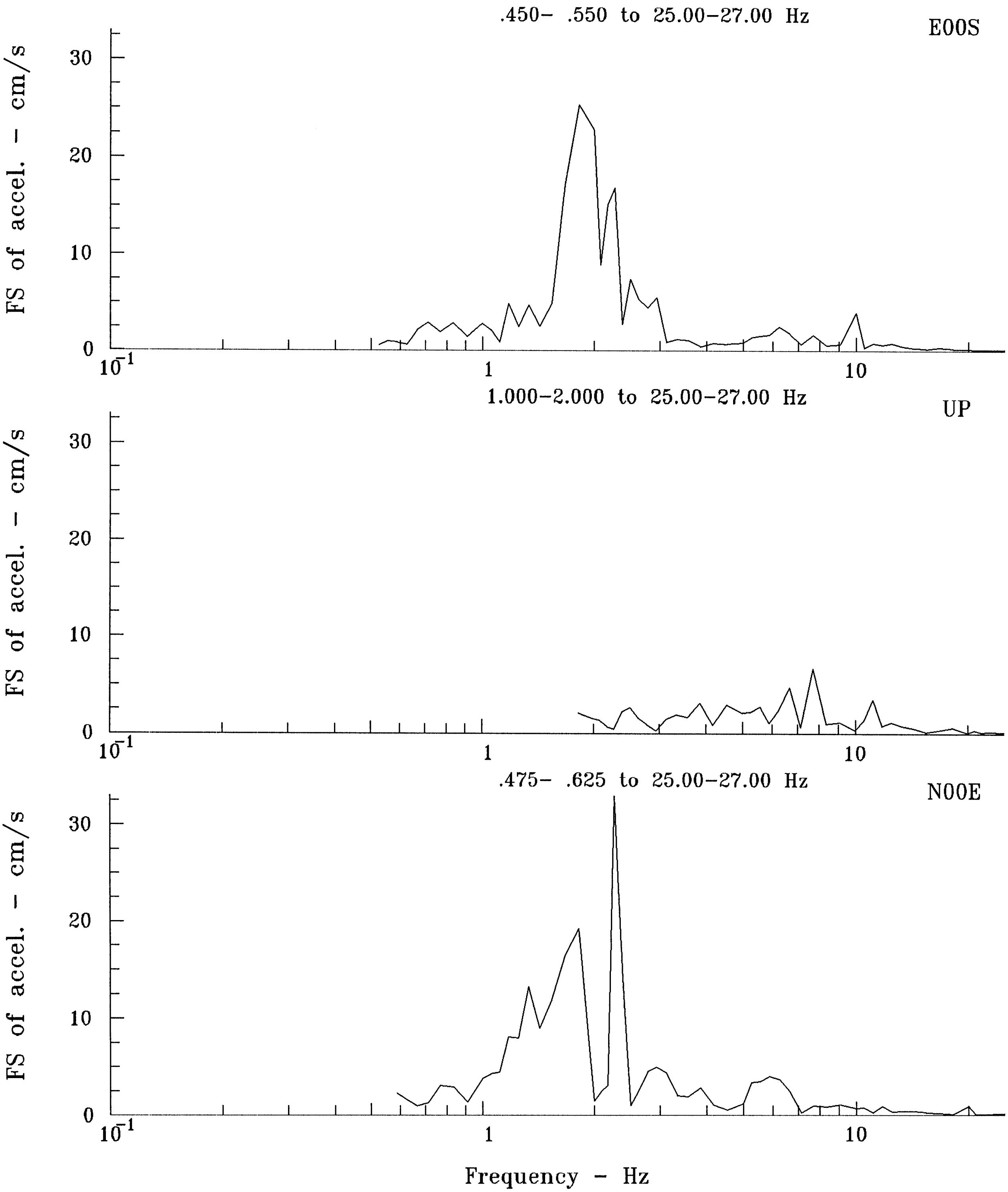


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 151) JAN 18, 1994 -0043 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 16.36 KM

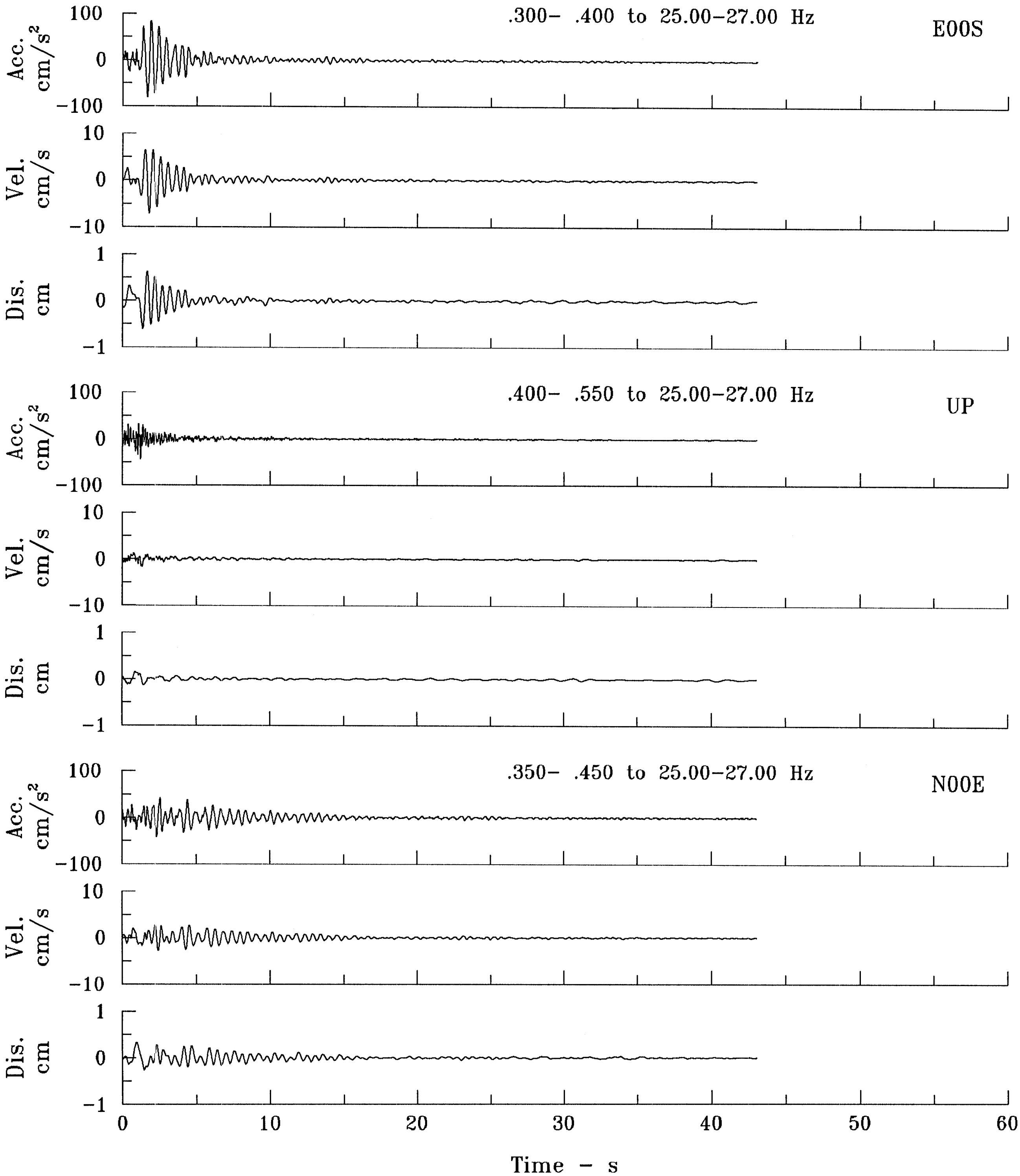


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 253) JAN 19, 1994 -0219 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 16.54 KM

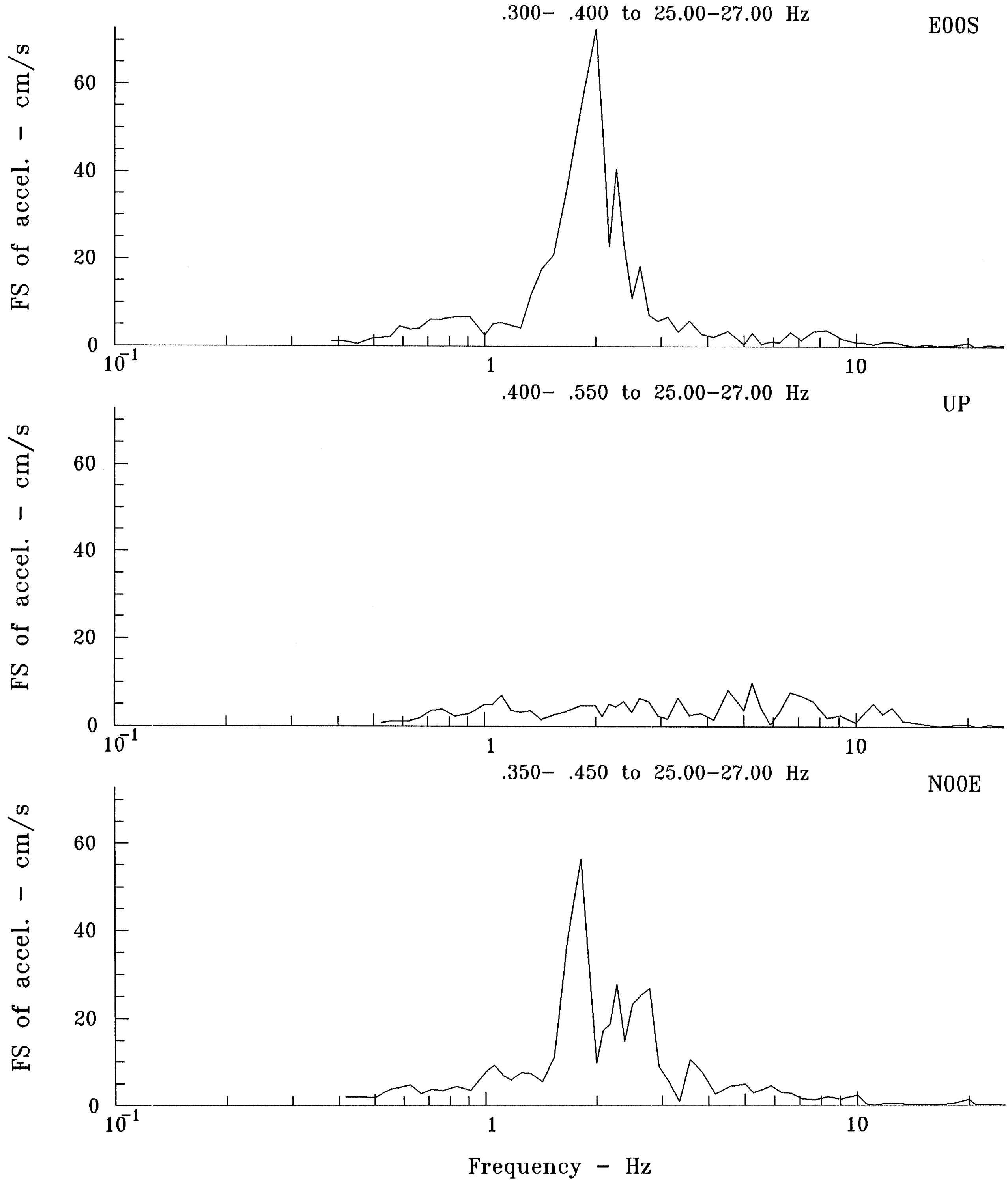


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 253) JAN 19, 1994 -0219 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 16.54 KM

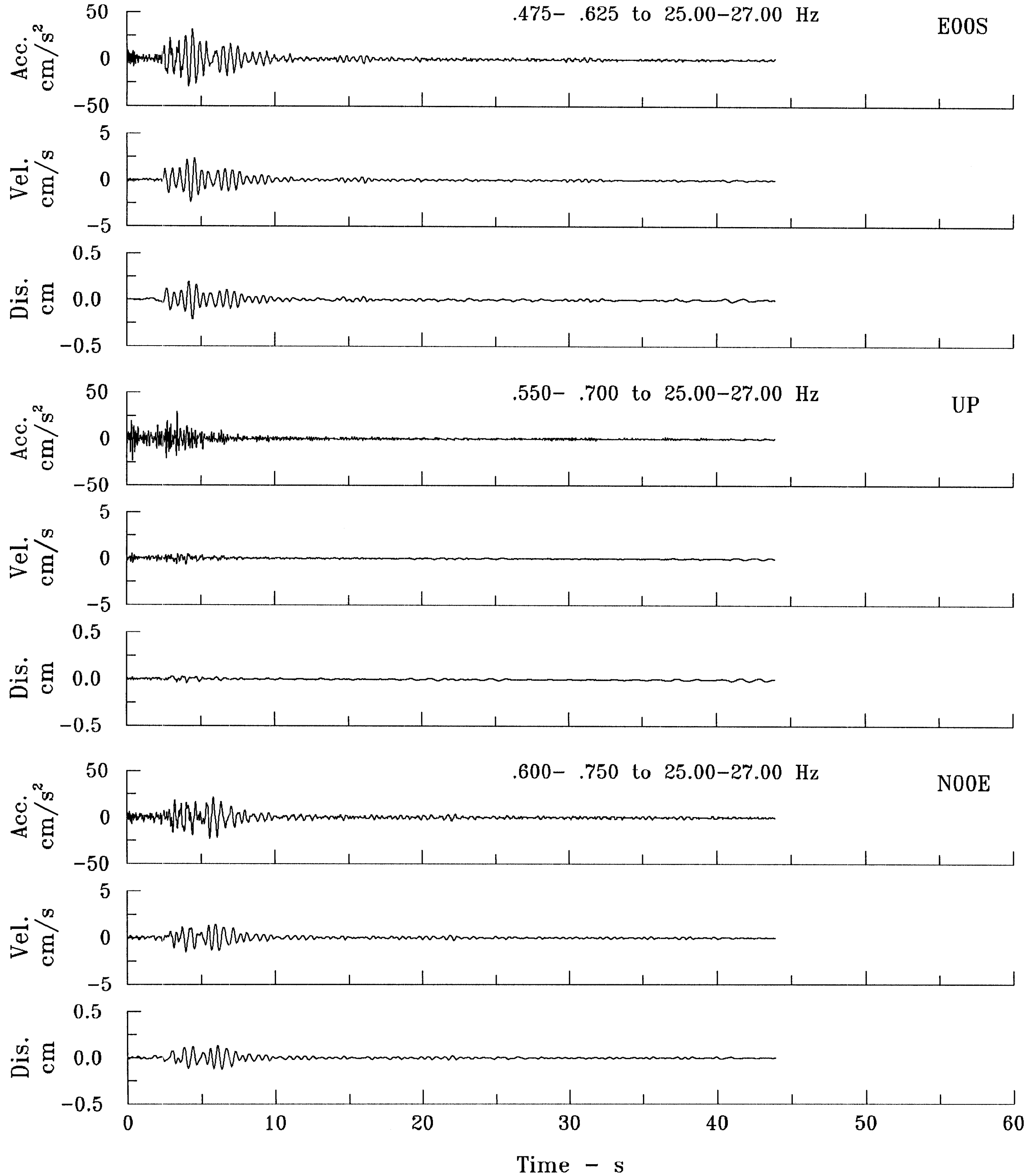


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 254) JAN 19, 1994 -2111 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 18.50 KM

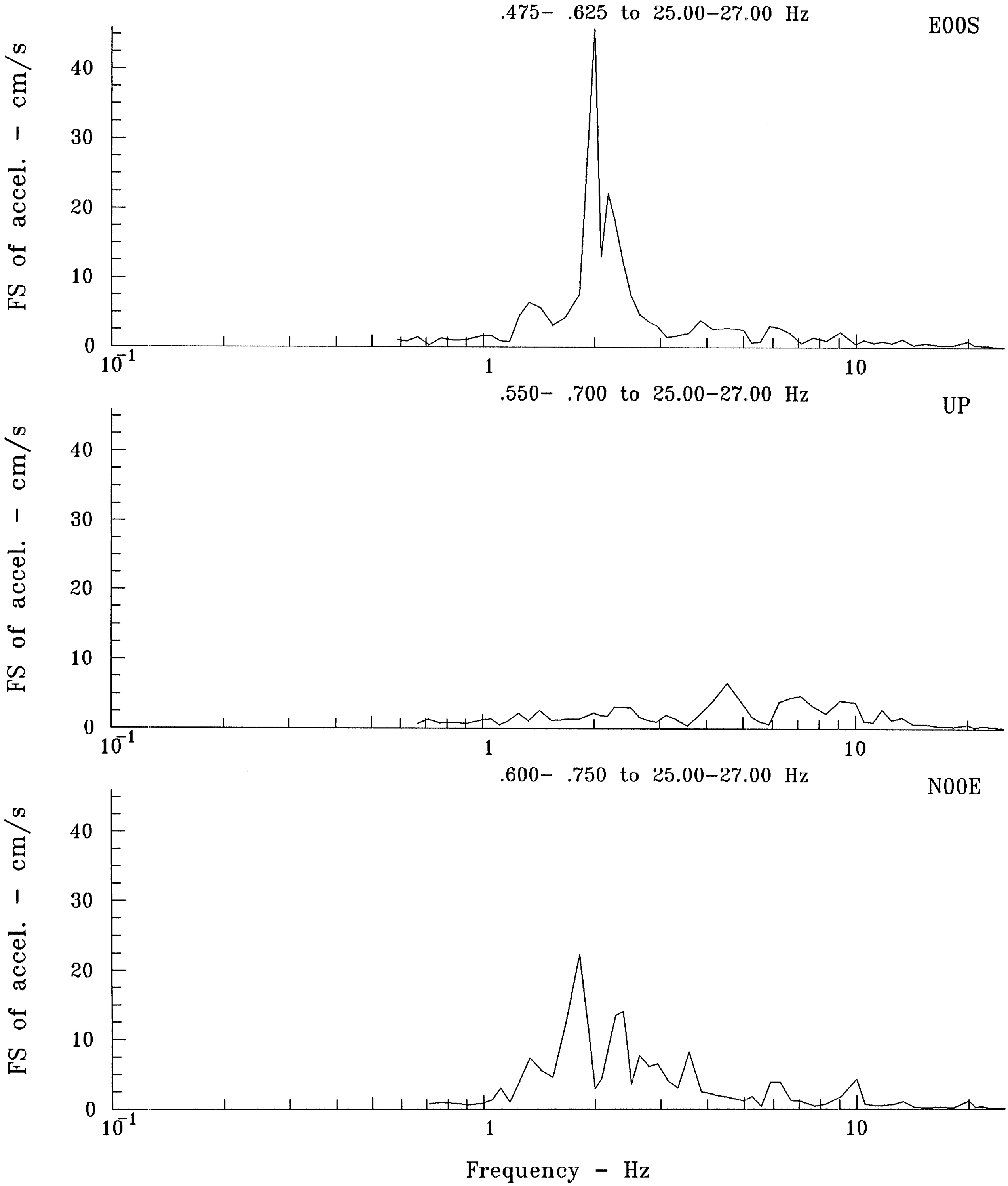


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 254) JAN 19, 1994 -2111 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 18.50 KM

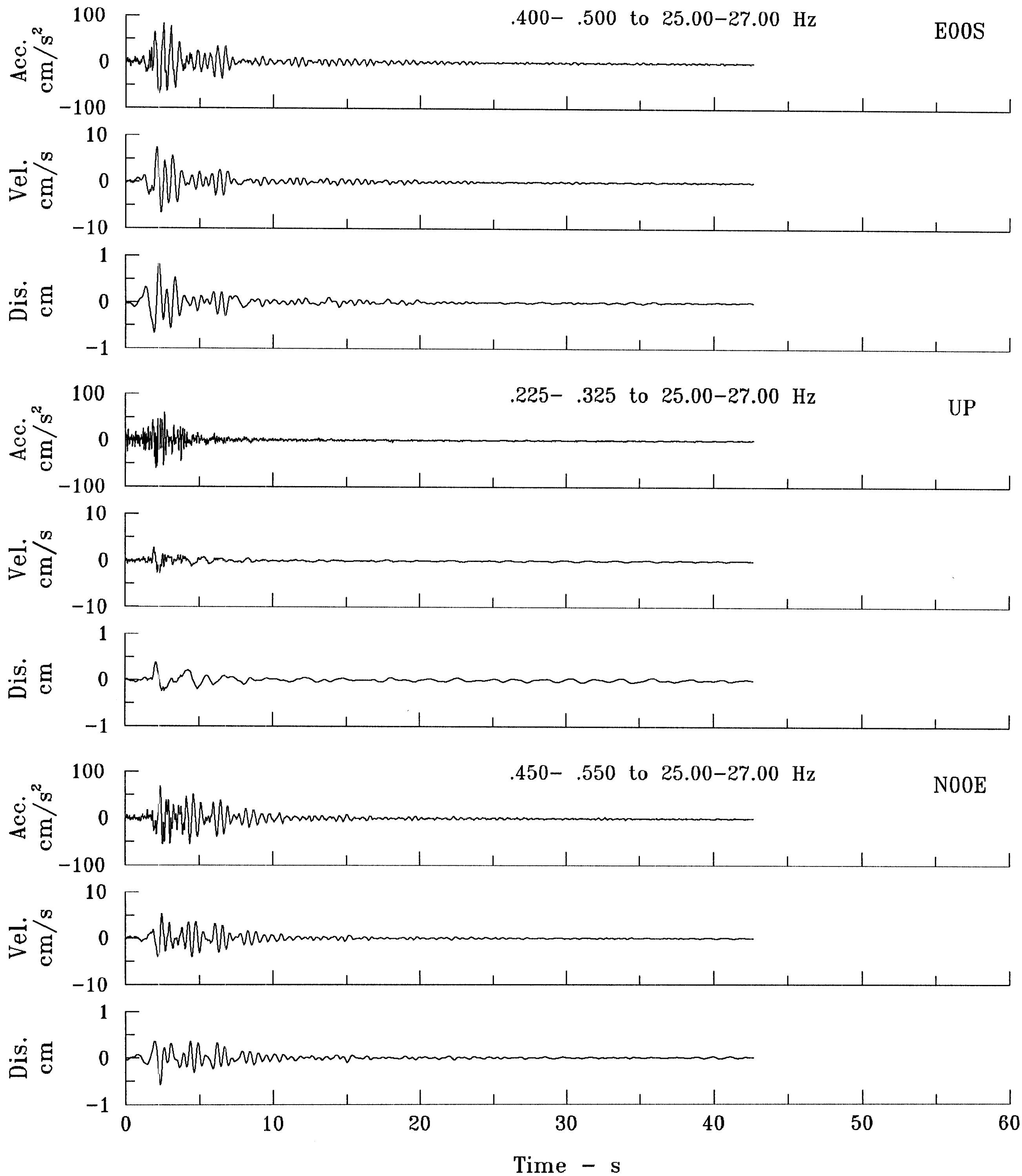


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 336) JAN 29, 1994 -1120 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 14.94 KM

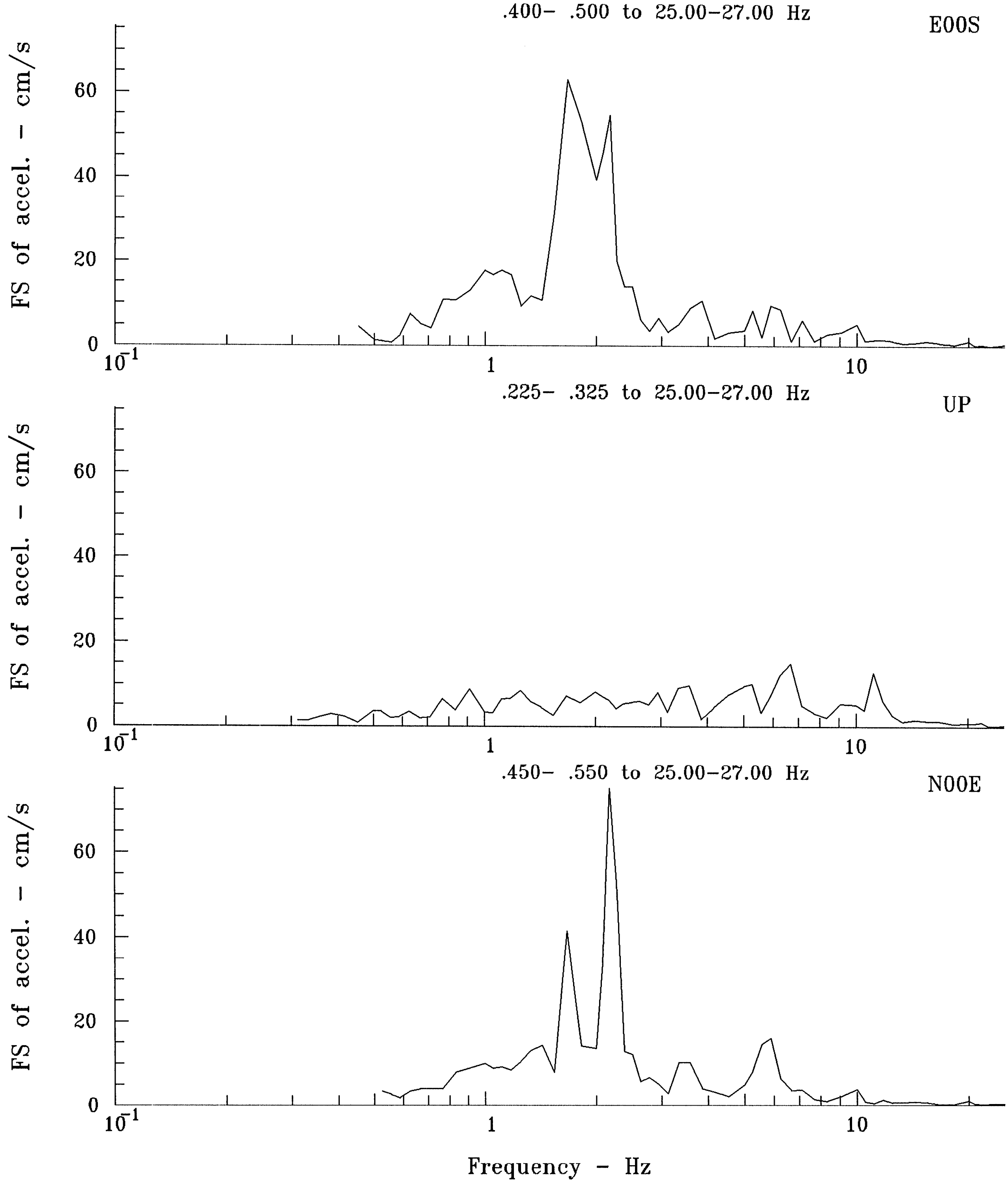


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 336) JAN 29, 1994 -1120 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 14.94 KM

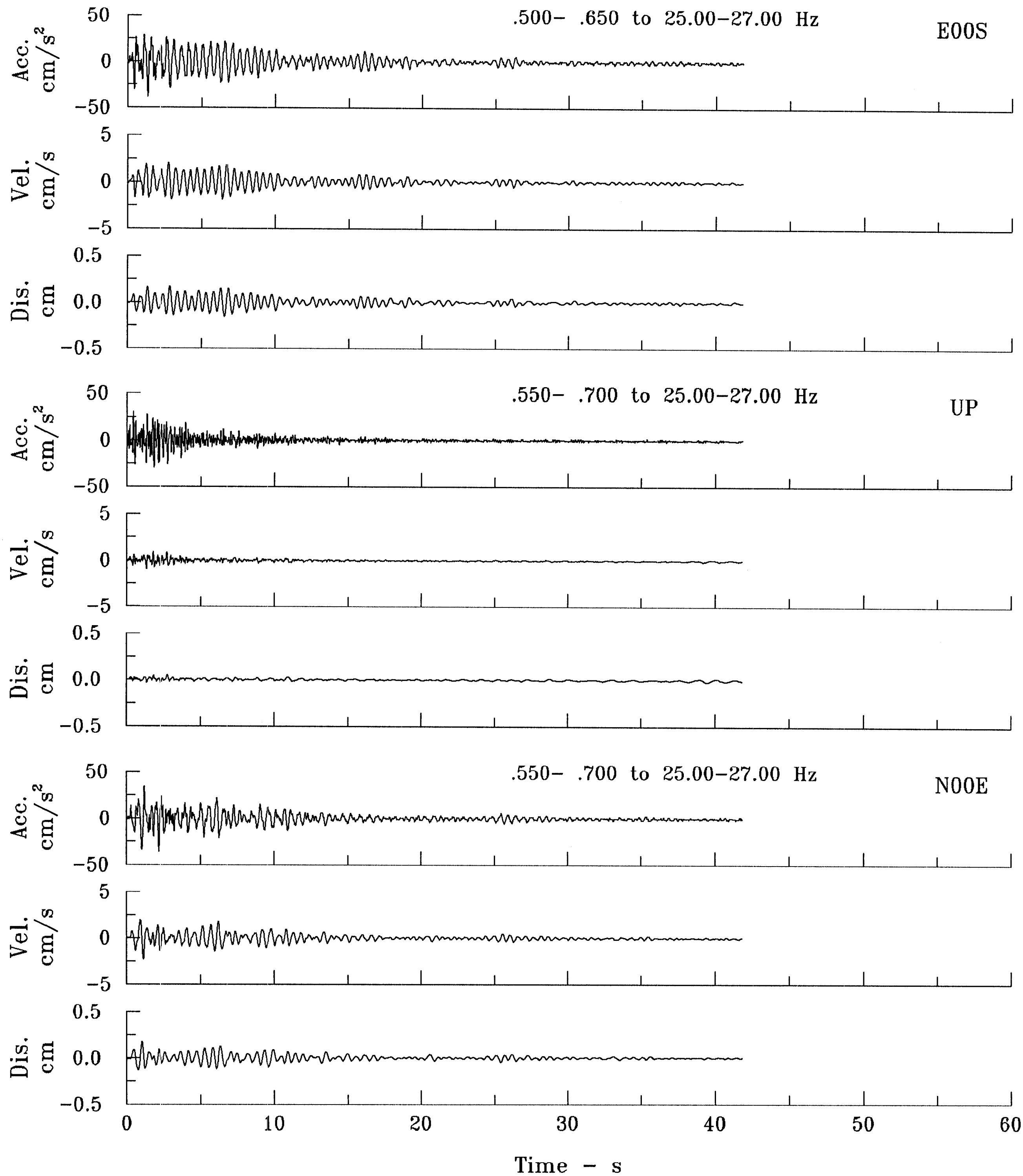


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 392) MAR 20, 1994 -2120 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 21.80 KM

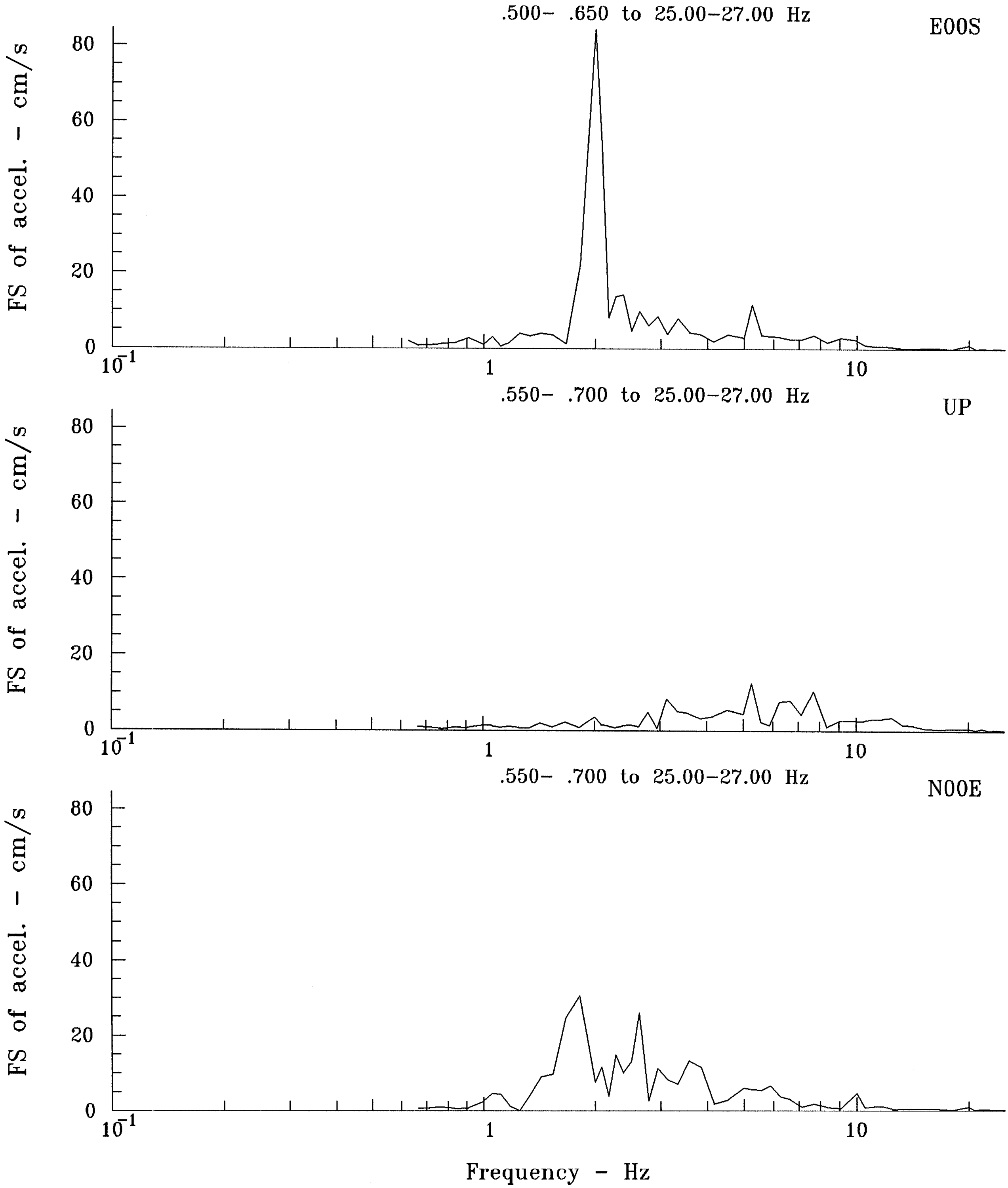


STATION USGS 5108 34.230 N, 118.712 W SER # 1276

SANTA SUSANA, ETEC Bldg #462 (6th Floor)

NORTHRIDGE EARTHQUAKE (aft. 392) MAR 20, 1994 -2120 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 21.80 KM

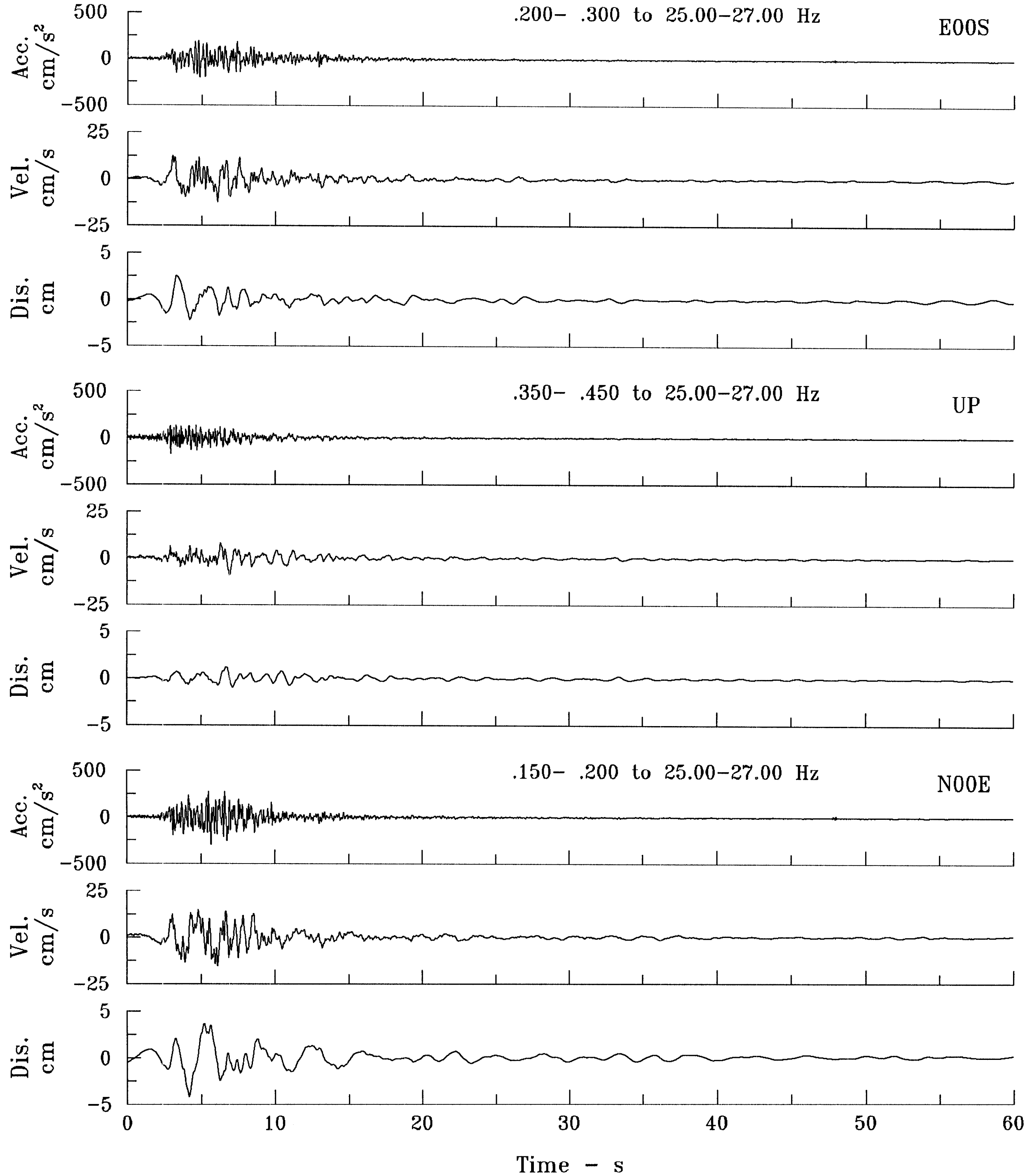


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 16.32 KM

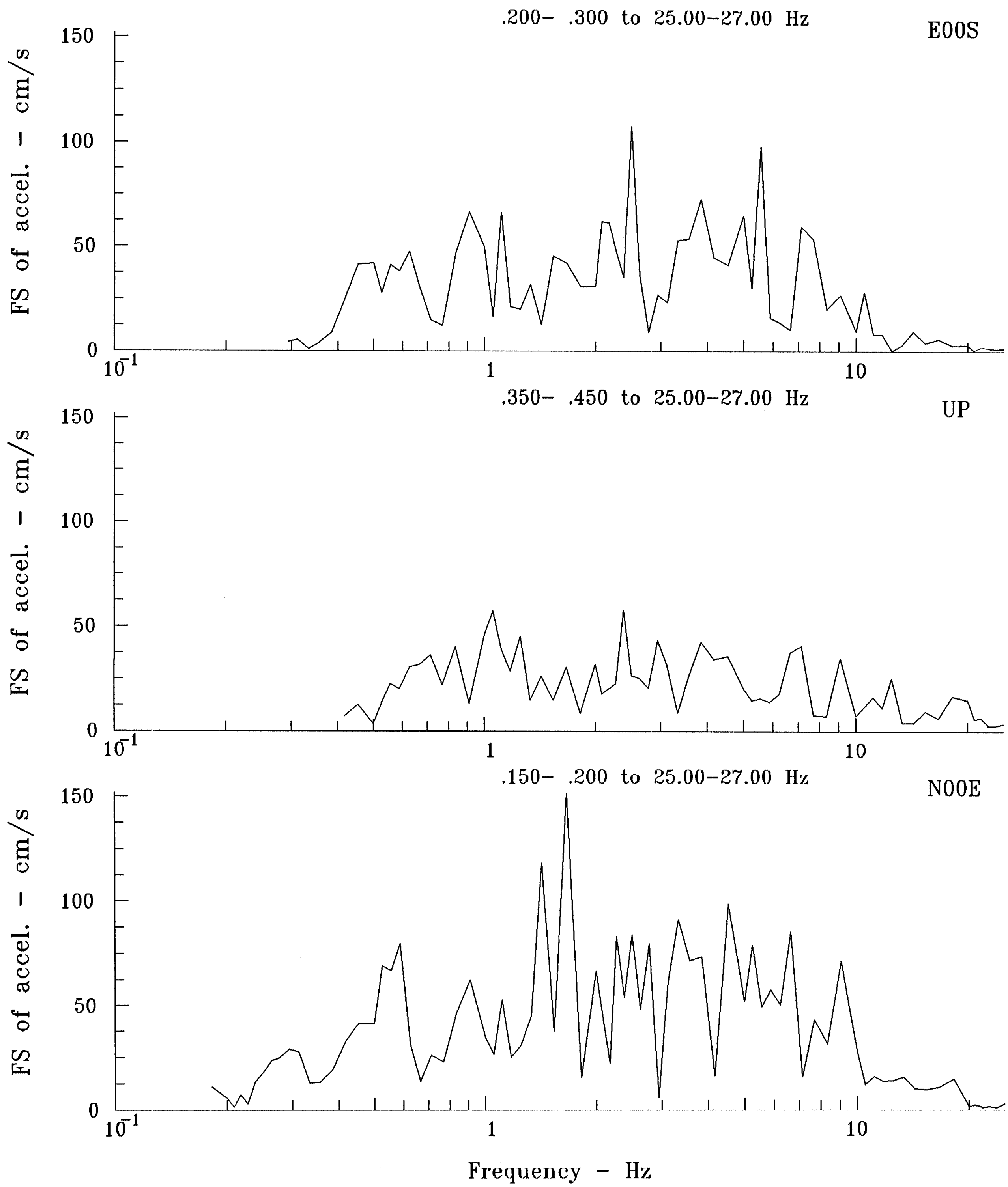


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 16.32 KM

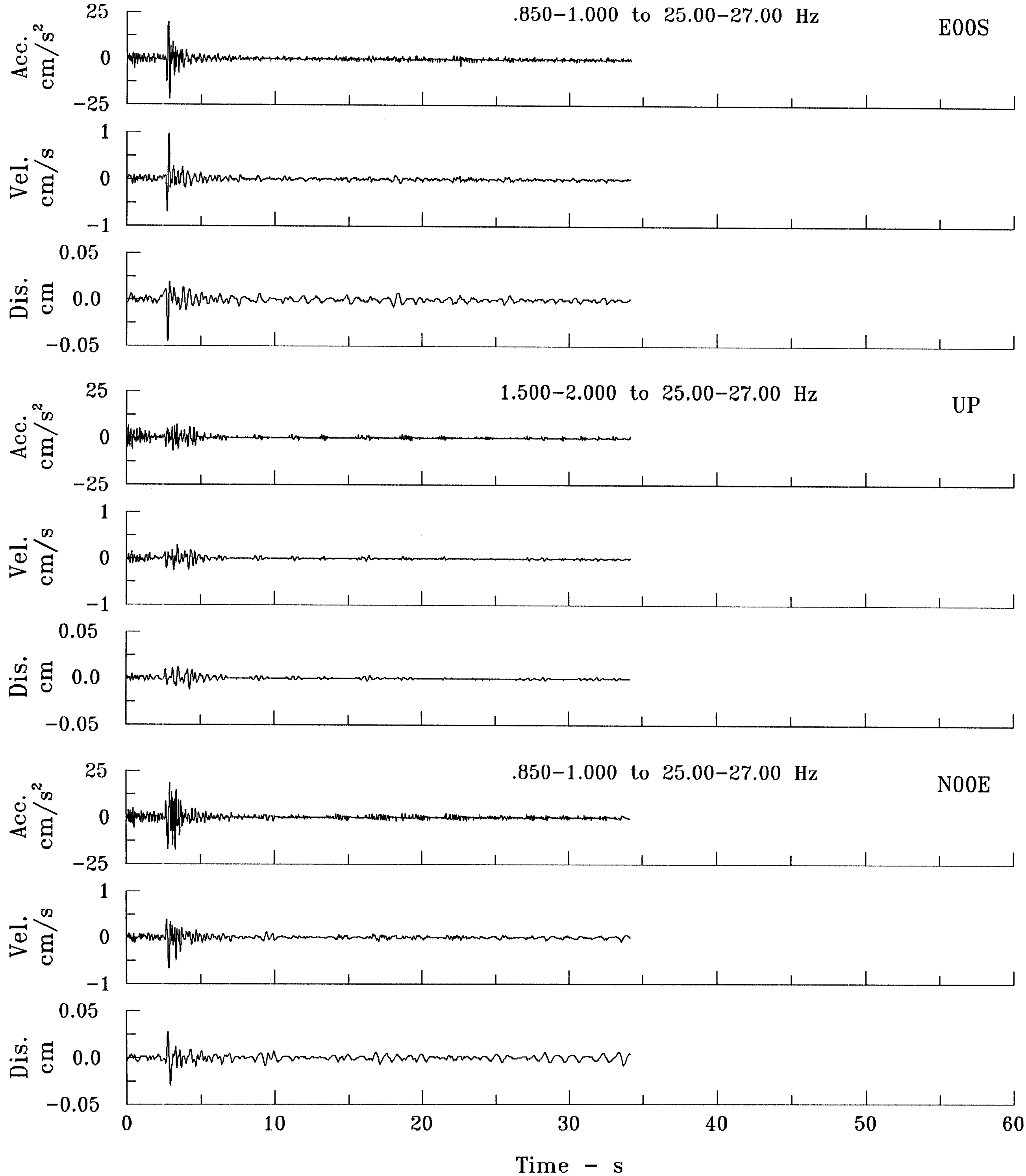


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 7) JAN 17, 1994 -1239 GMT

MAGNITUDE = 4.9 EPICENTRAL DISTANCE = 16.80 KM

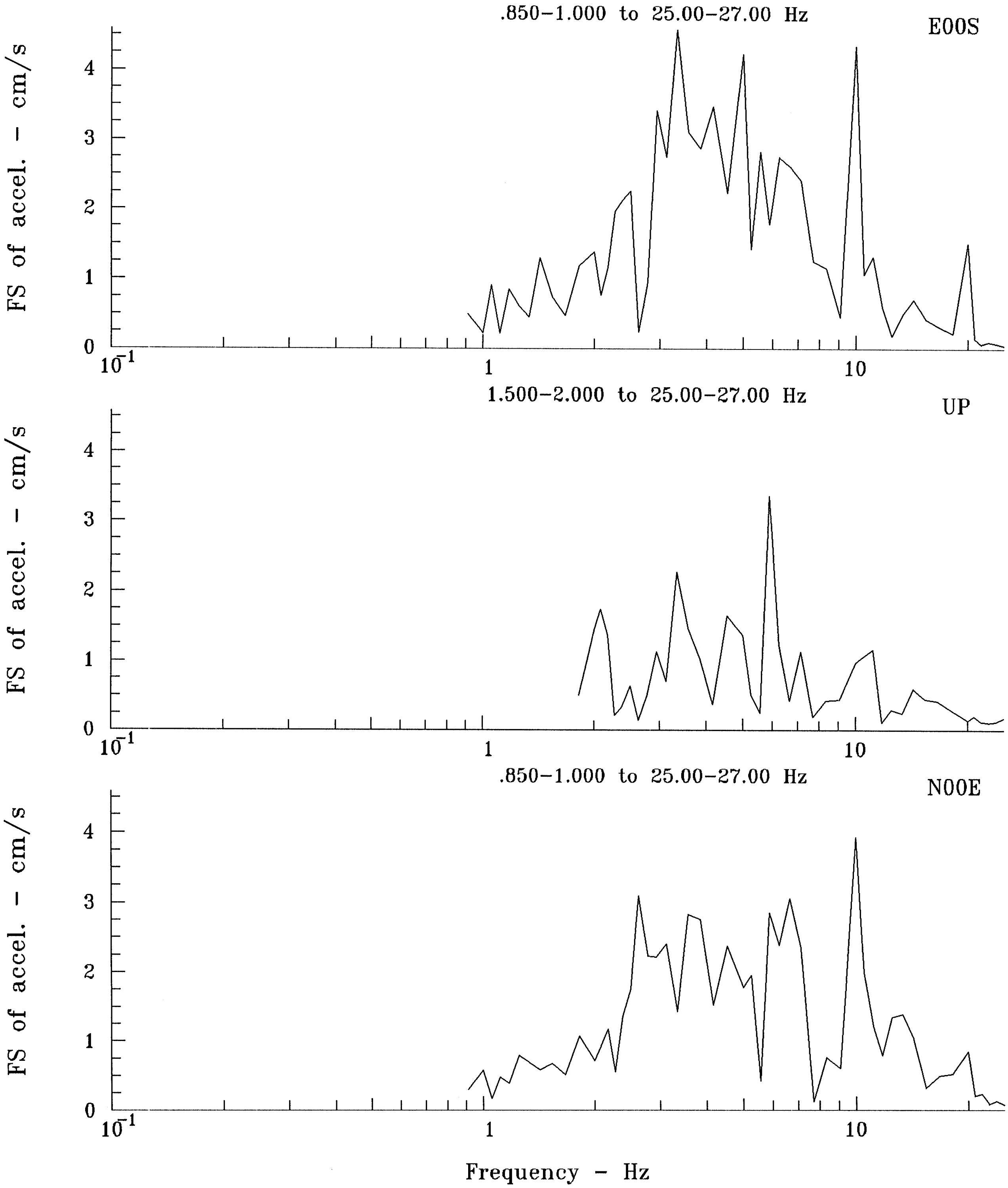


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 7) JAN 17, 1994 -1239 GMT

MAGNITUDE = 4.9 EPICENTRAL DISTANCE = 16.80 KM

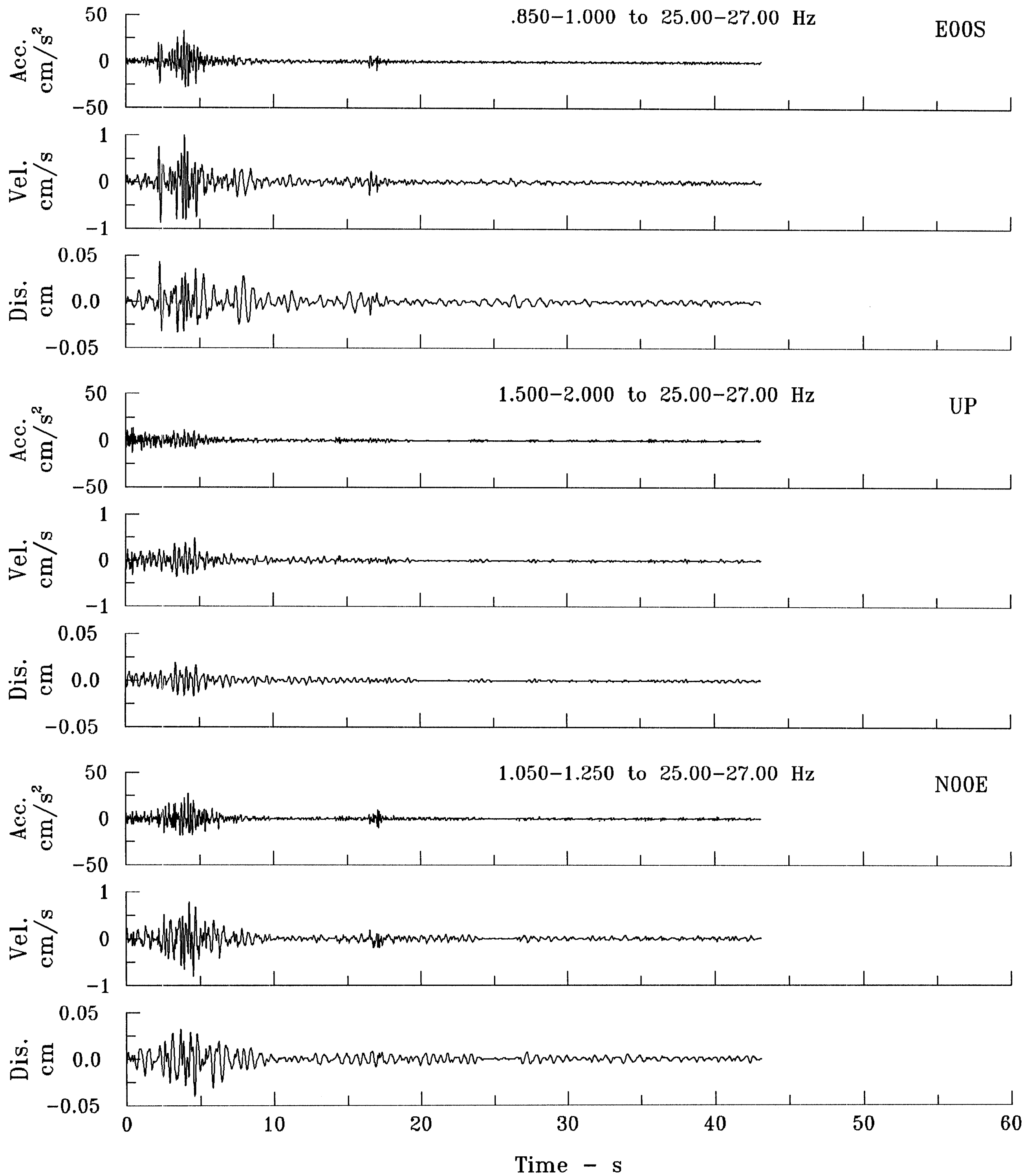


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 9) JAN 17, 1994 -1240 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 16.12 KM

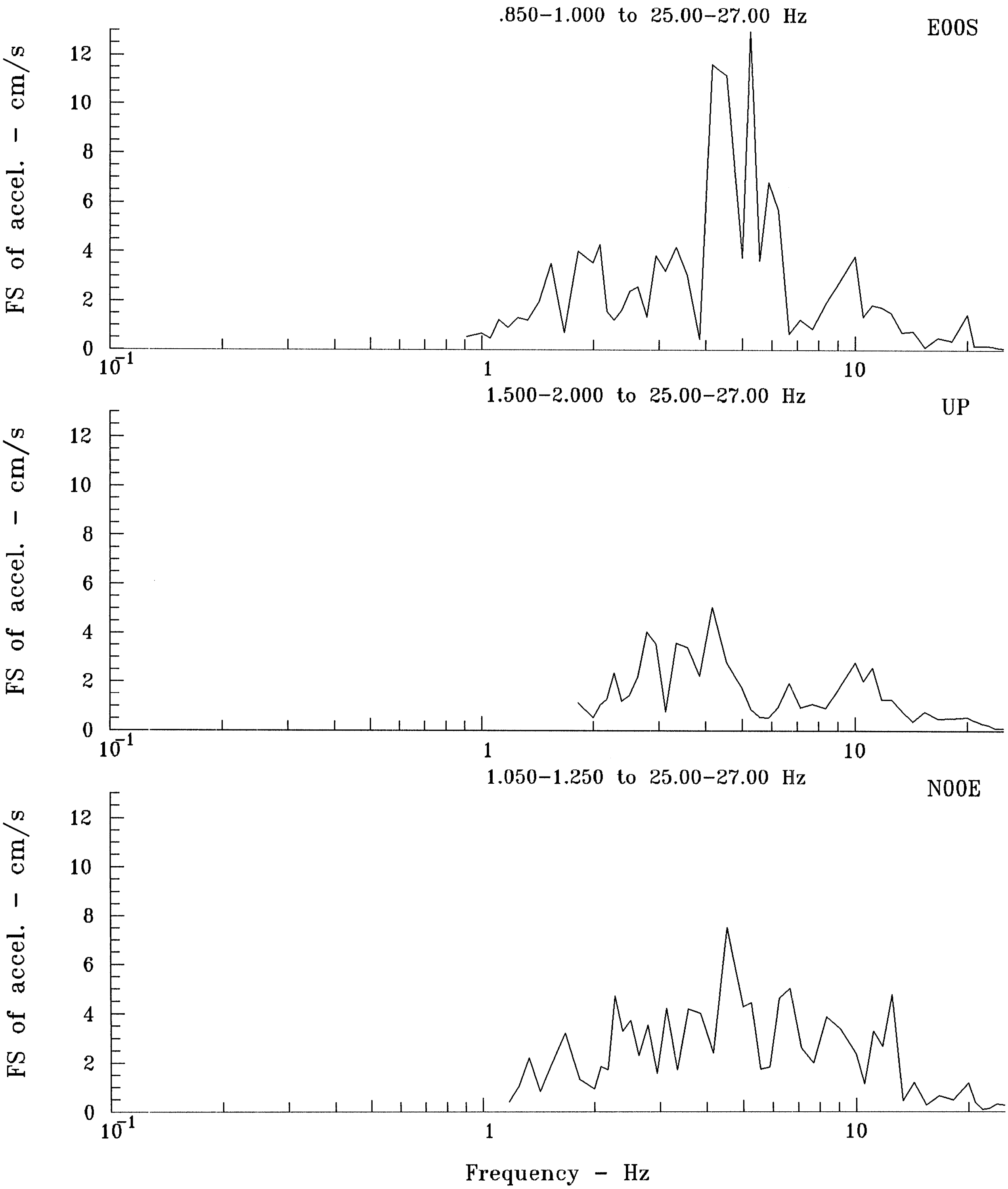


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 9) JAN 17, 1994 -1240 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 16.12 KM

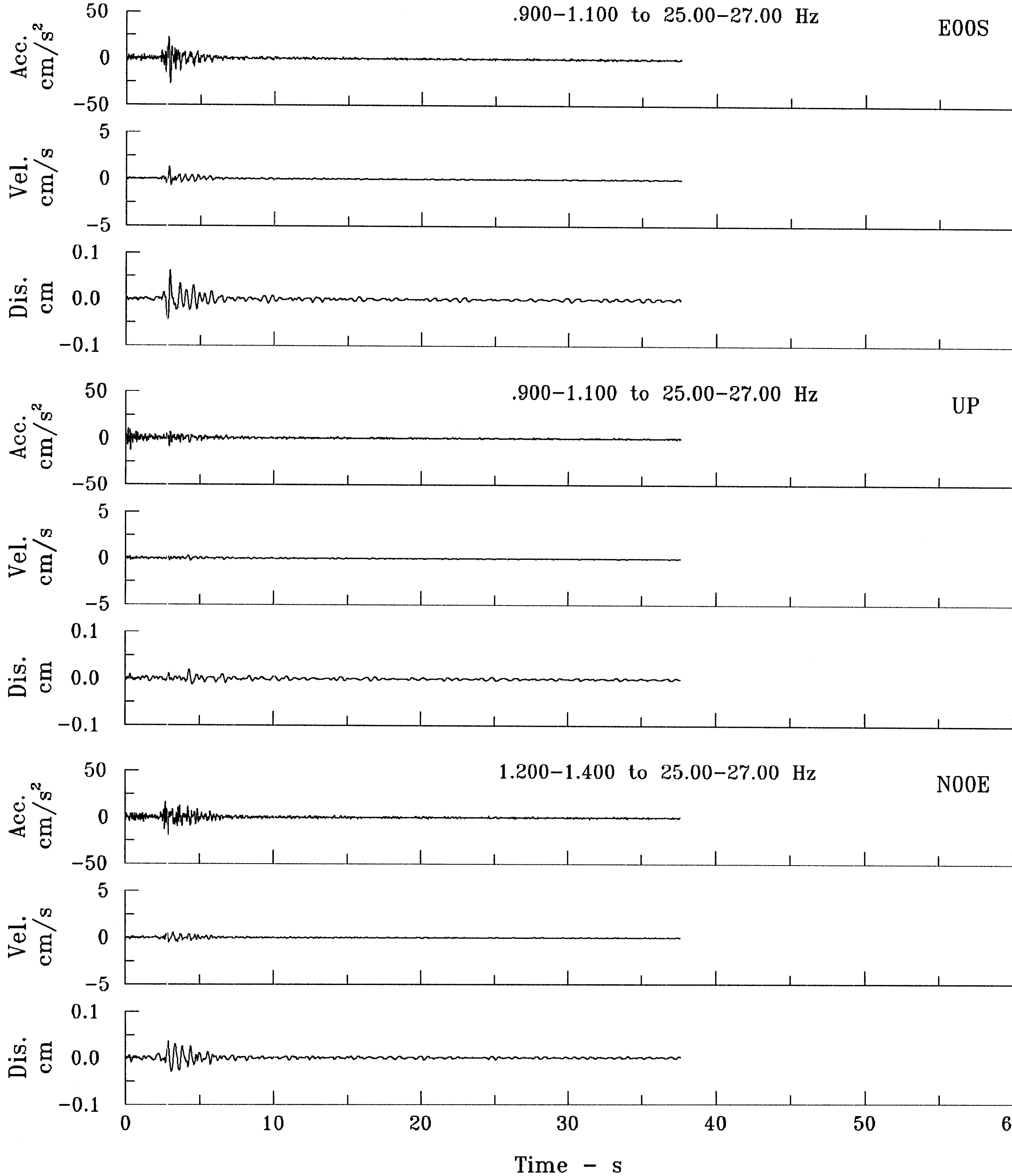


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 100) JAN 17, 1994 -1756 GMT

MAGNITUDE = 4.6 EPICENTRAL DISTANCE = 12.89 KM

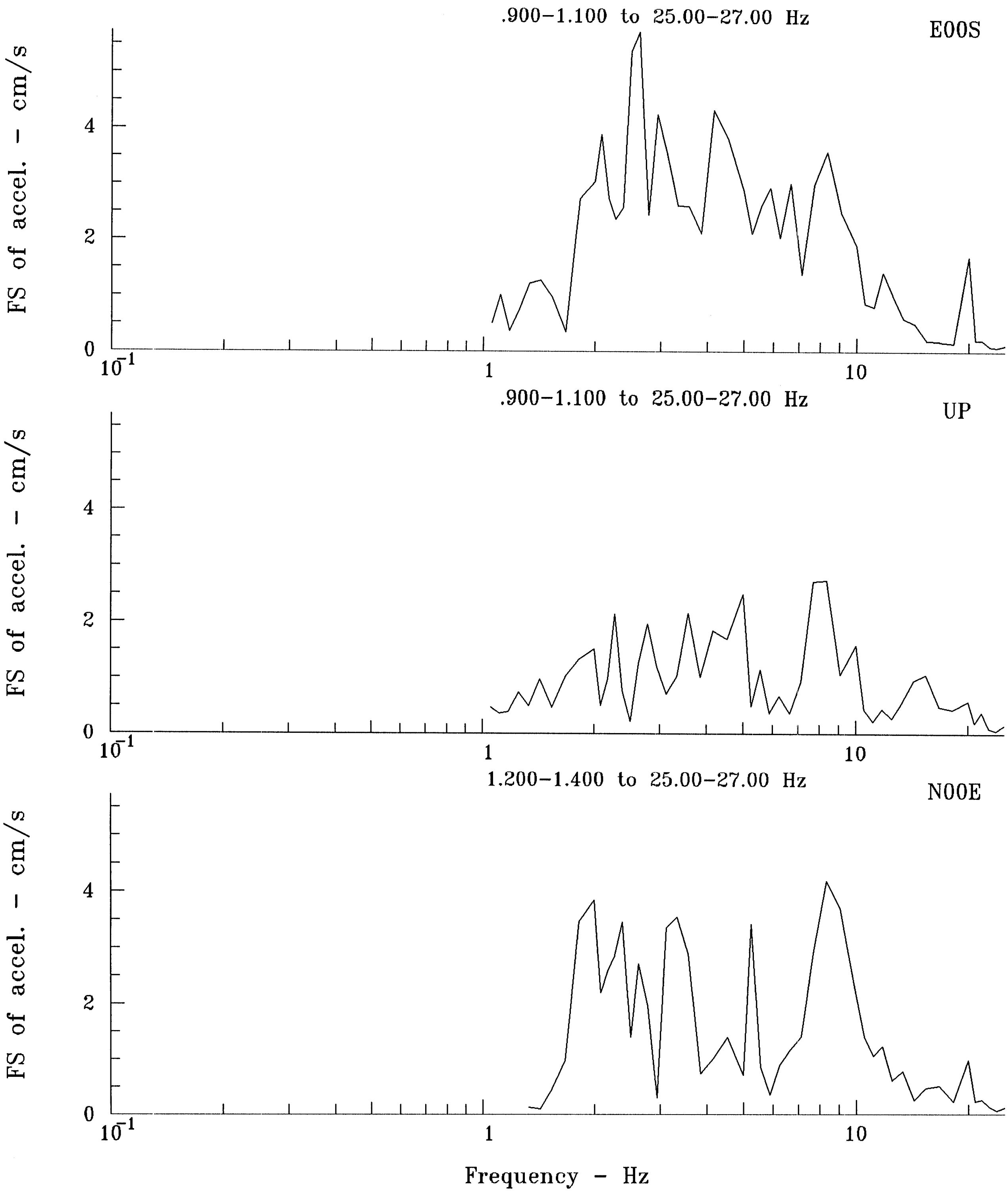


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 100) JAN 17, 1994 -1756 GMT

MAGNITUDE = 4.6 EPICENTRAL DISTANCE = 12.89 KM

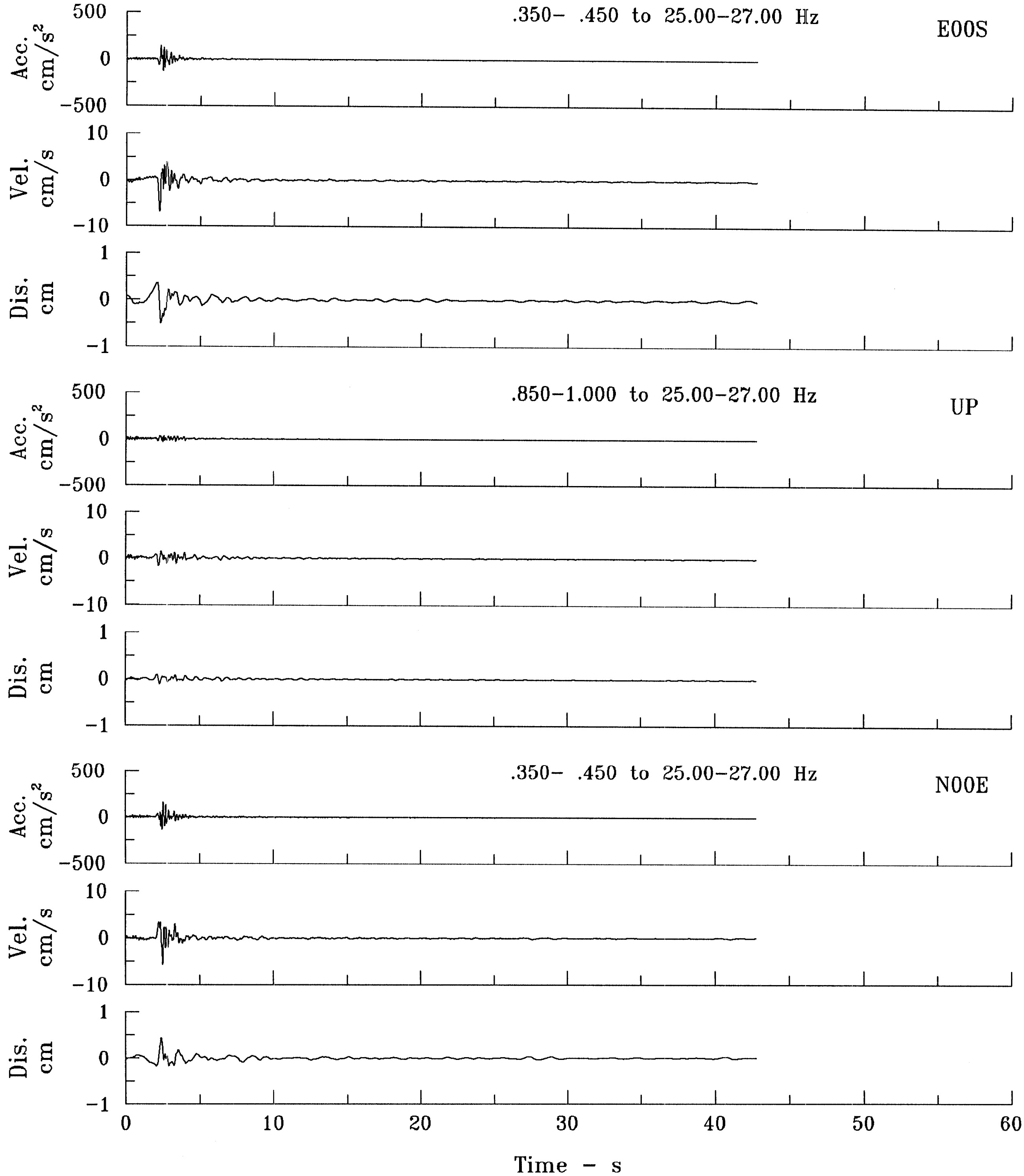


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 129) JAN 17, 1994 -2046 GMT

MAGNITUDE = 4.9 EPICENTRAL DISTANCE = 15.73 KM

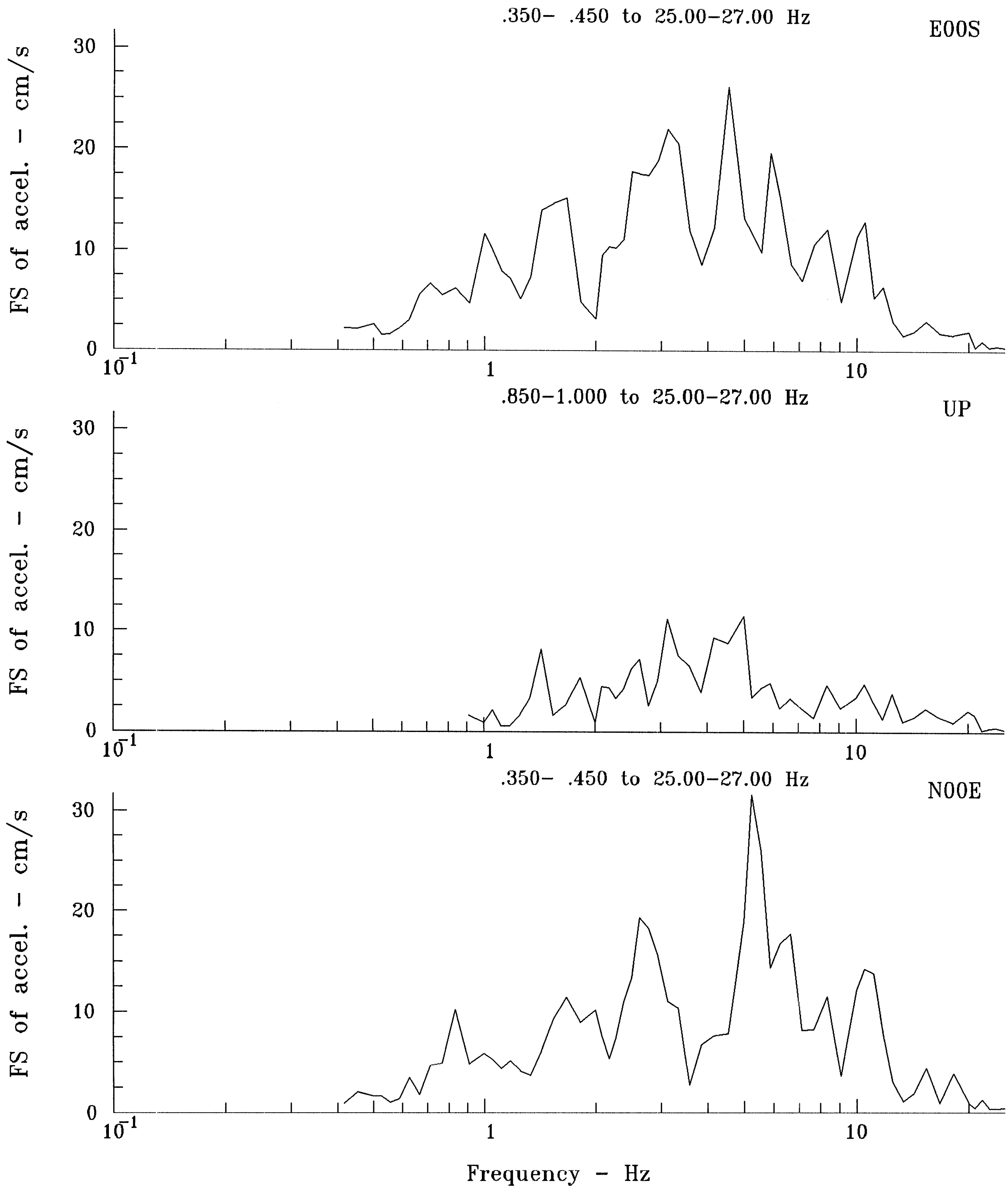


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 129) JAN 17, 1994 -2046 GMT

MAGNITUDE = 4.9 EPICENTRAL DISTANCE = 15.73 KM

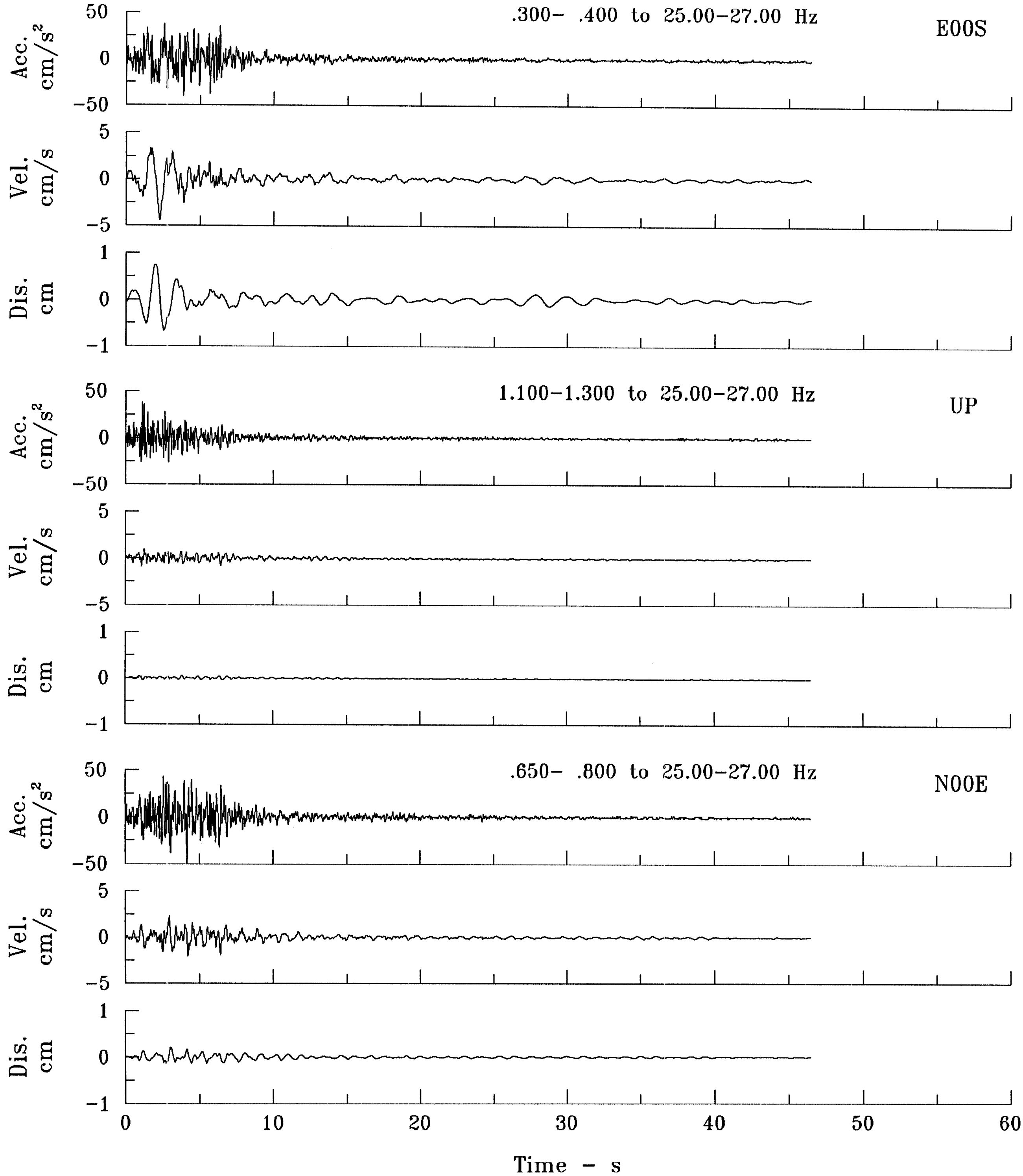


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 142) JAN 17, 1994 -2333 GMT

MAGNITUDE = 5.6 EPICENTRAL DISTANCE = 10.87 KM

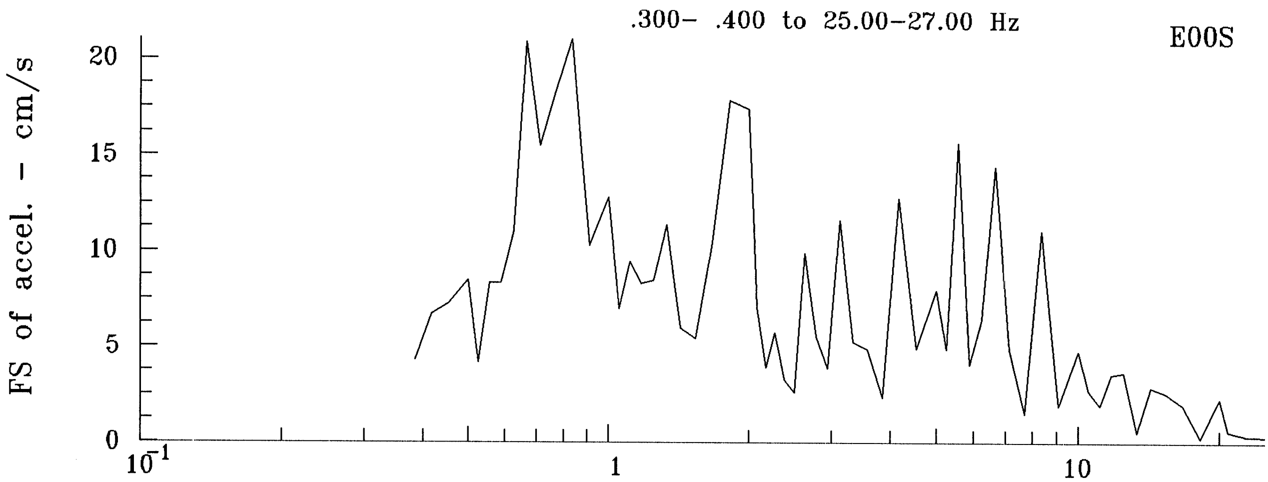


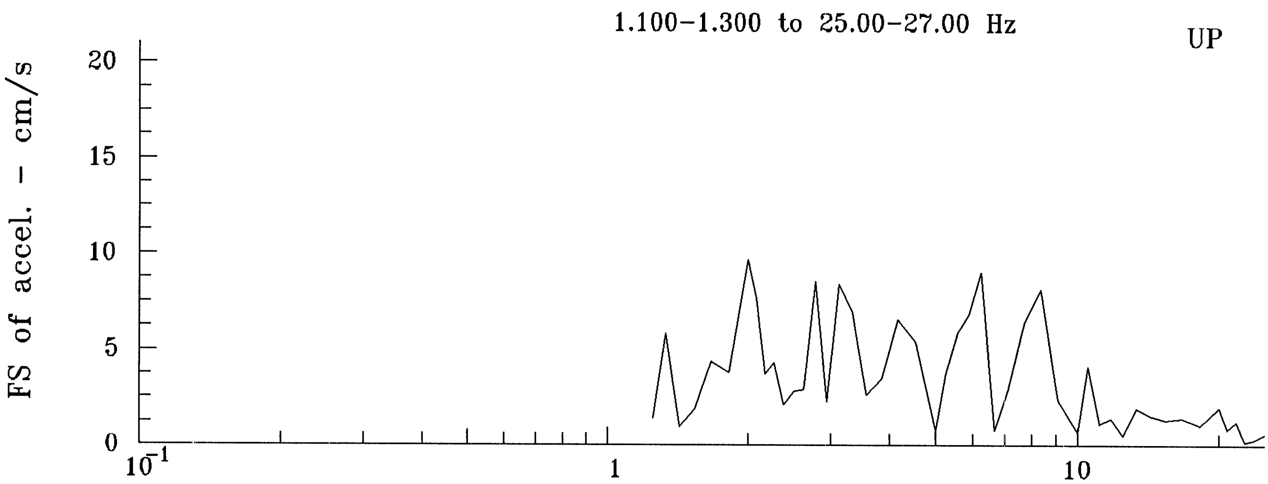
STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

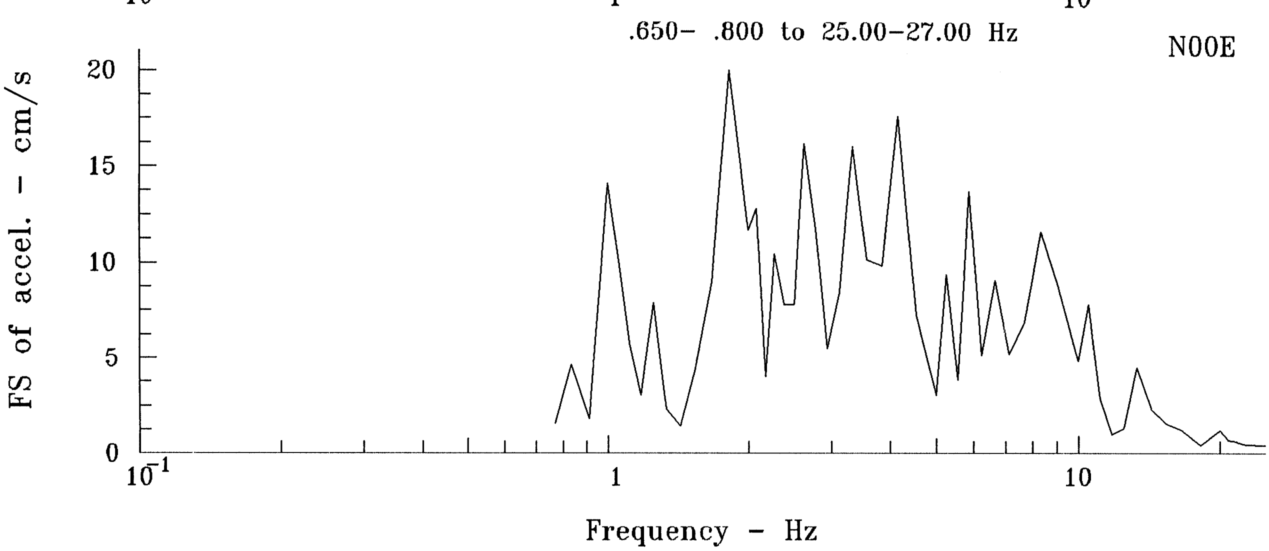
SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 142) JAN 17, 1994 -2333 GMT

MAGNITUDE = 5.6 EPICENTRAL DISTANCE = 10.87 KM





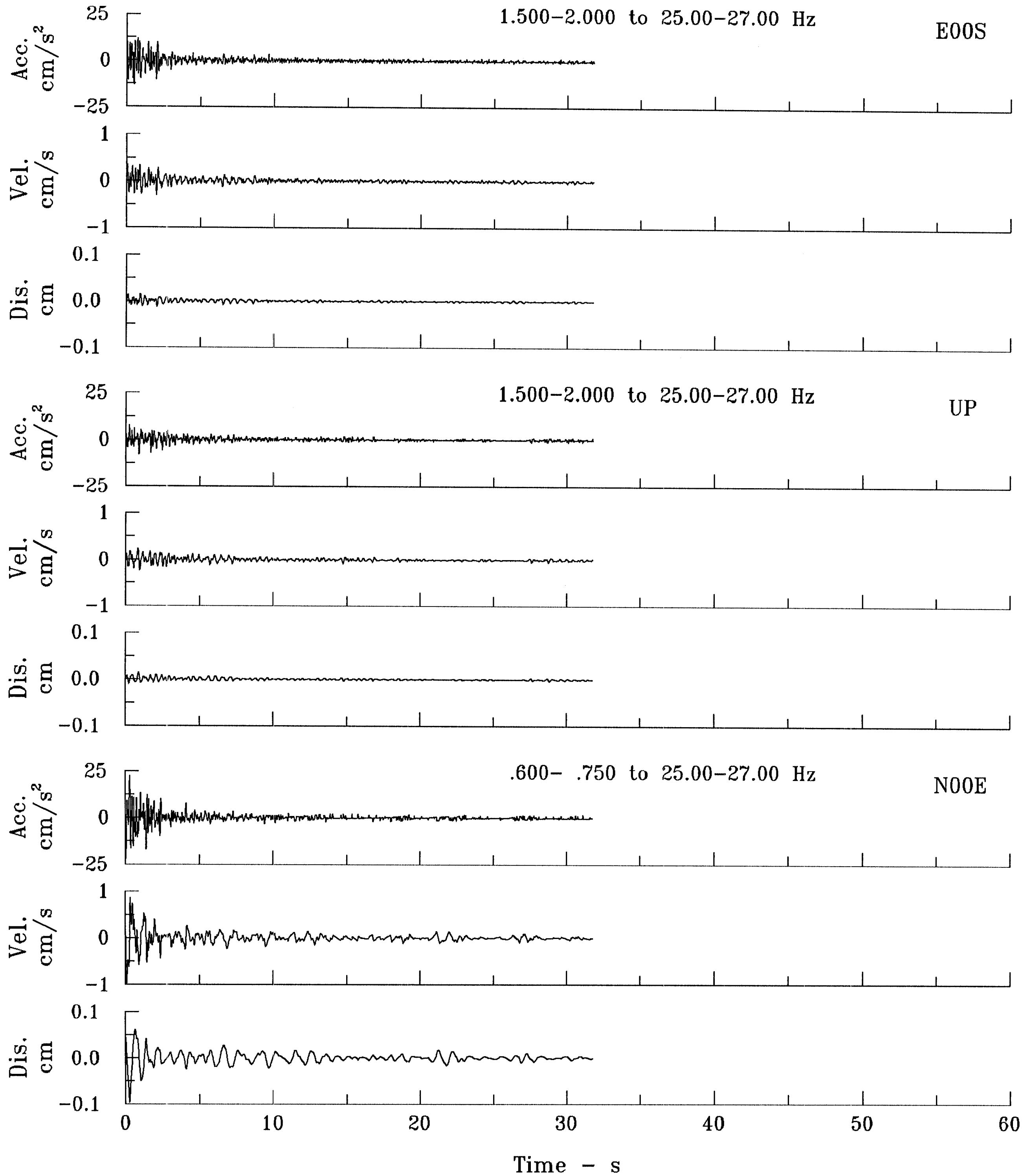


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 151) JAN 18, 1994 -0043 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 16.36 KM

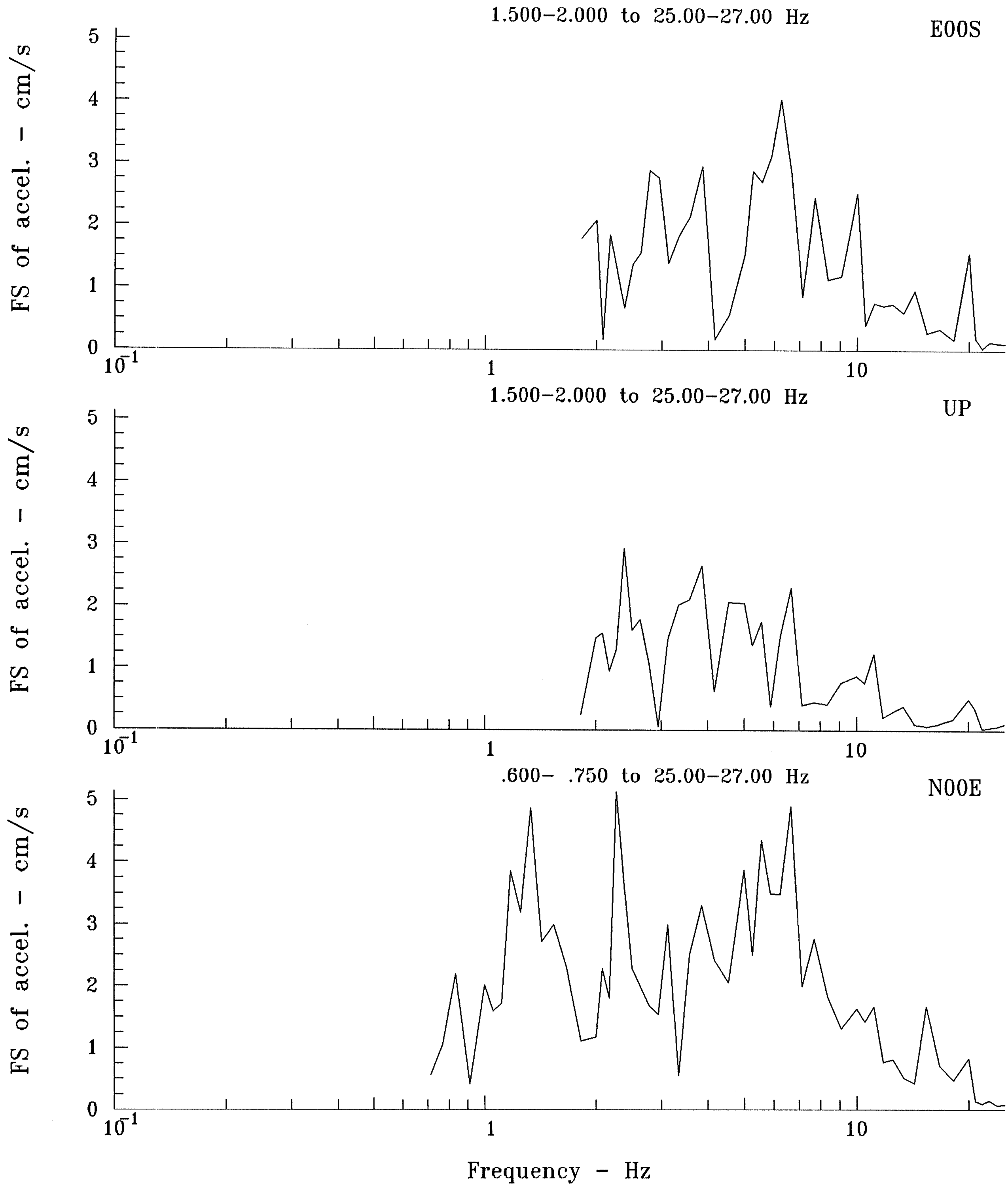


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 151) JAN 18, 1994 -0043 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 16.36 KM

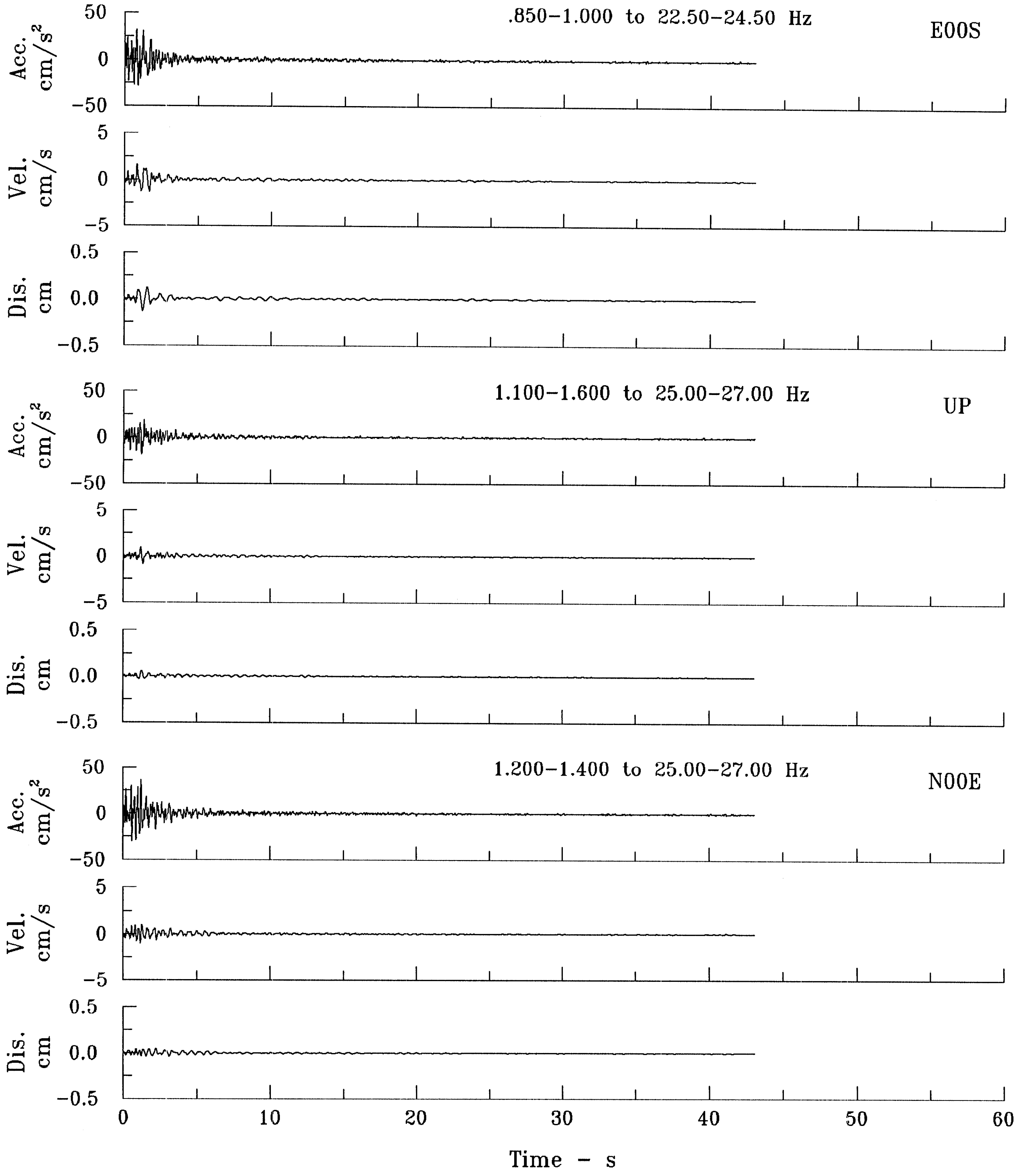


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 253) JAN 19, 1994 -0219 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 16.54 KM

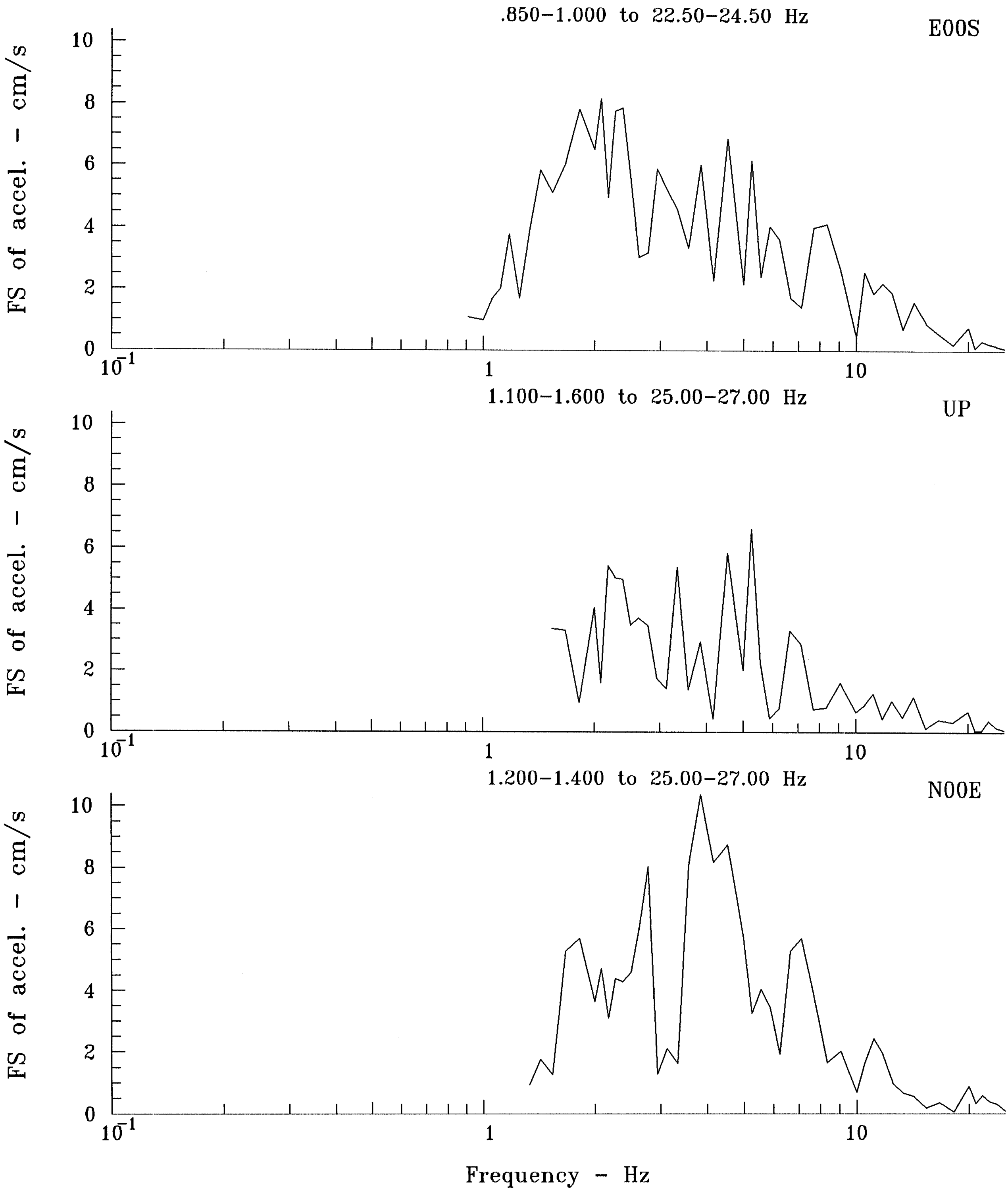


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 253) JAN 19, 1994 -0219 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 16.54 KM

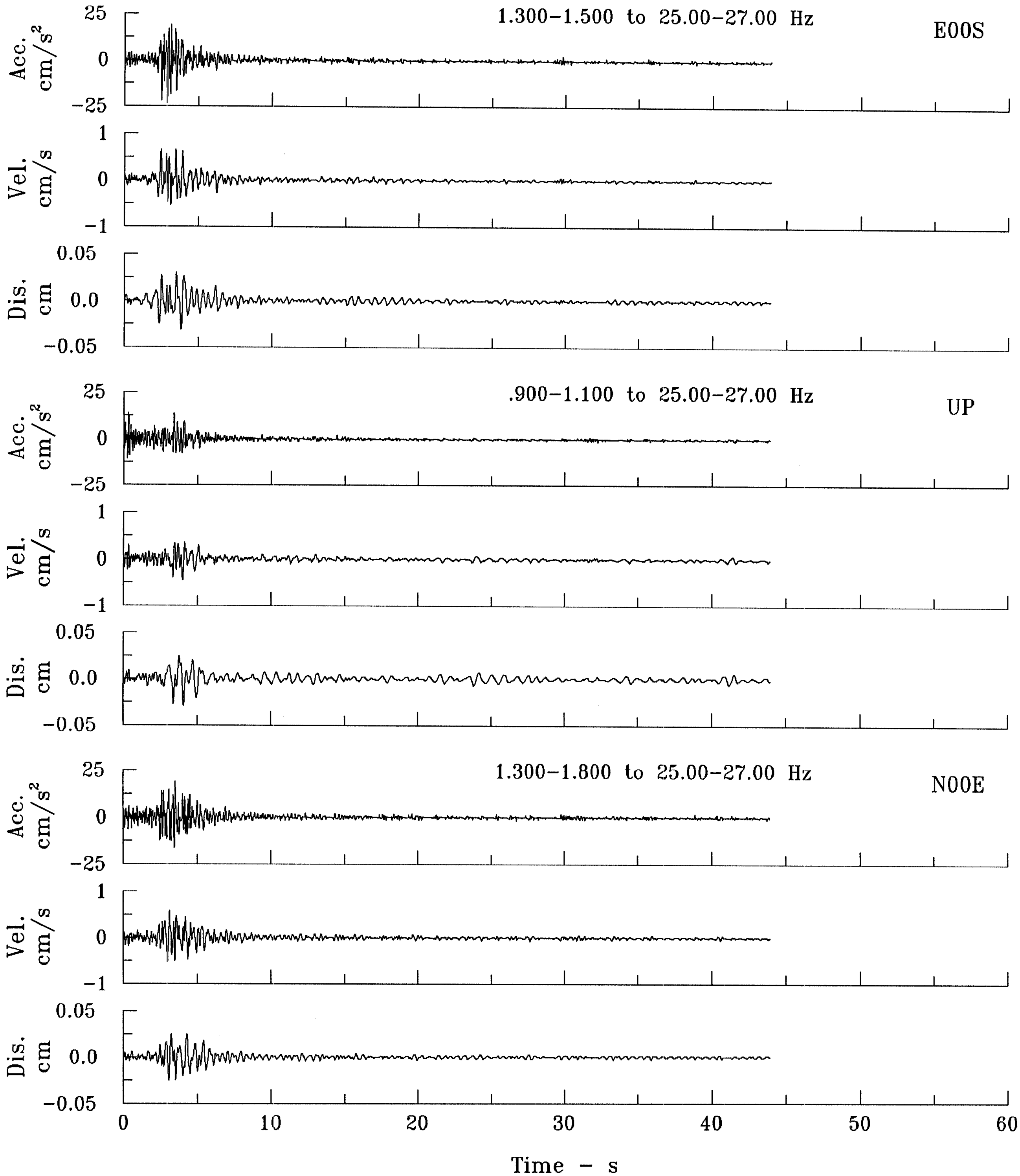


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 254) JAN 19, 1994 -2111 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 18.50 KM

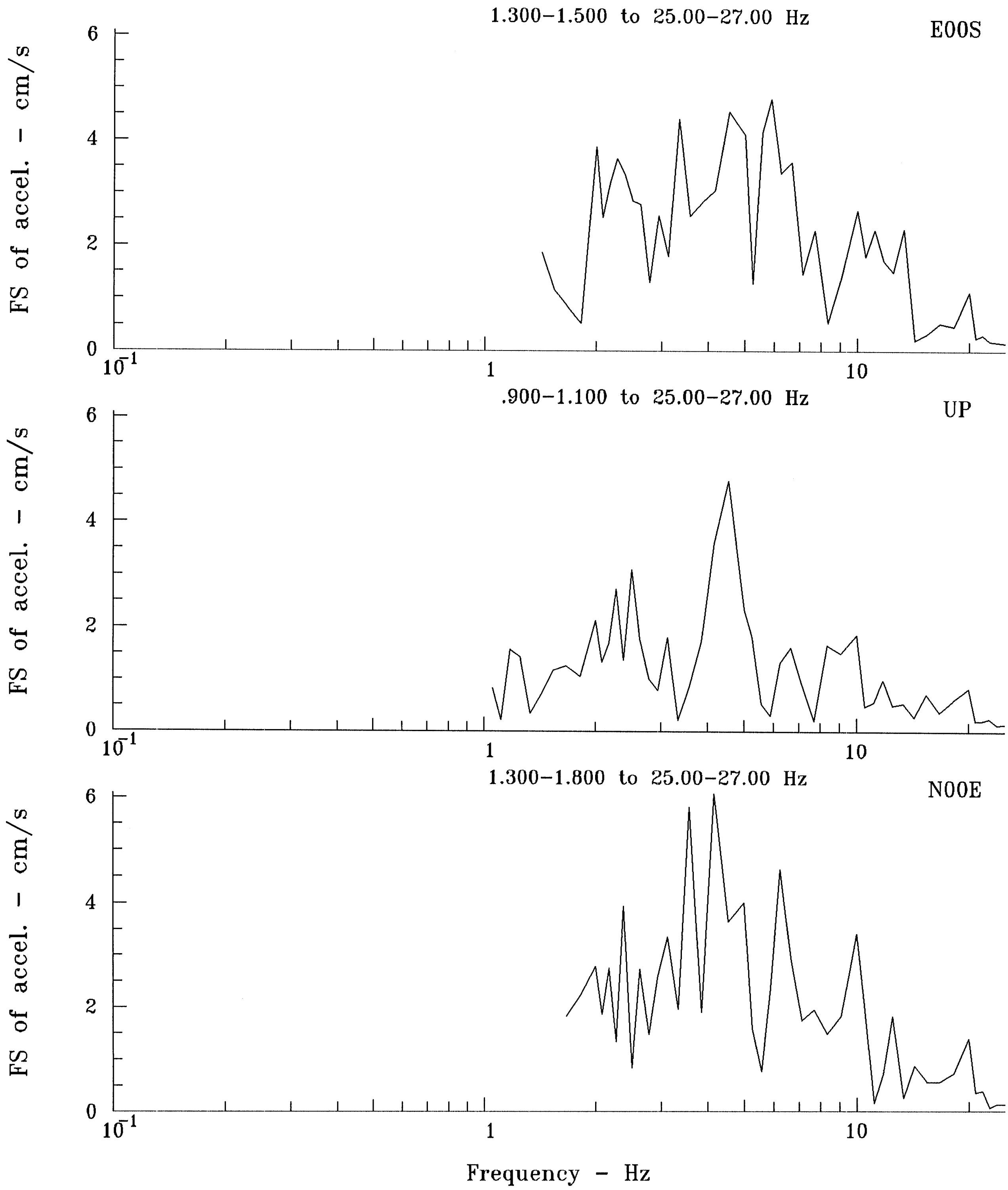


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 254) JAN 19, 1994 -2111 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 18.50 KM

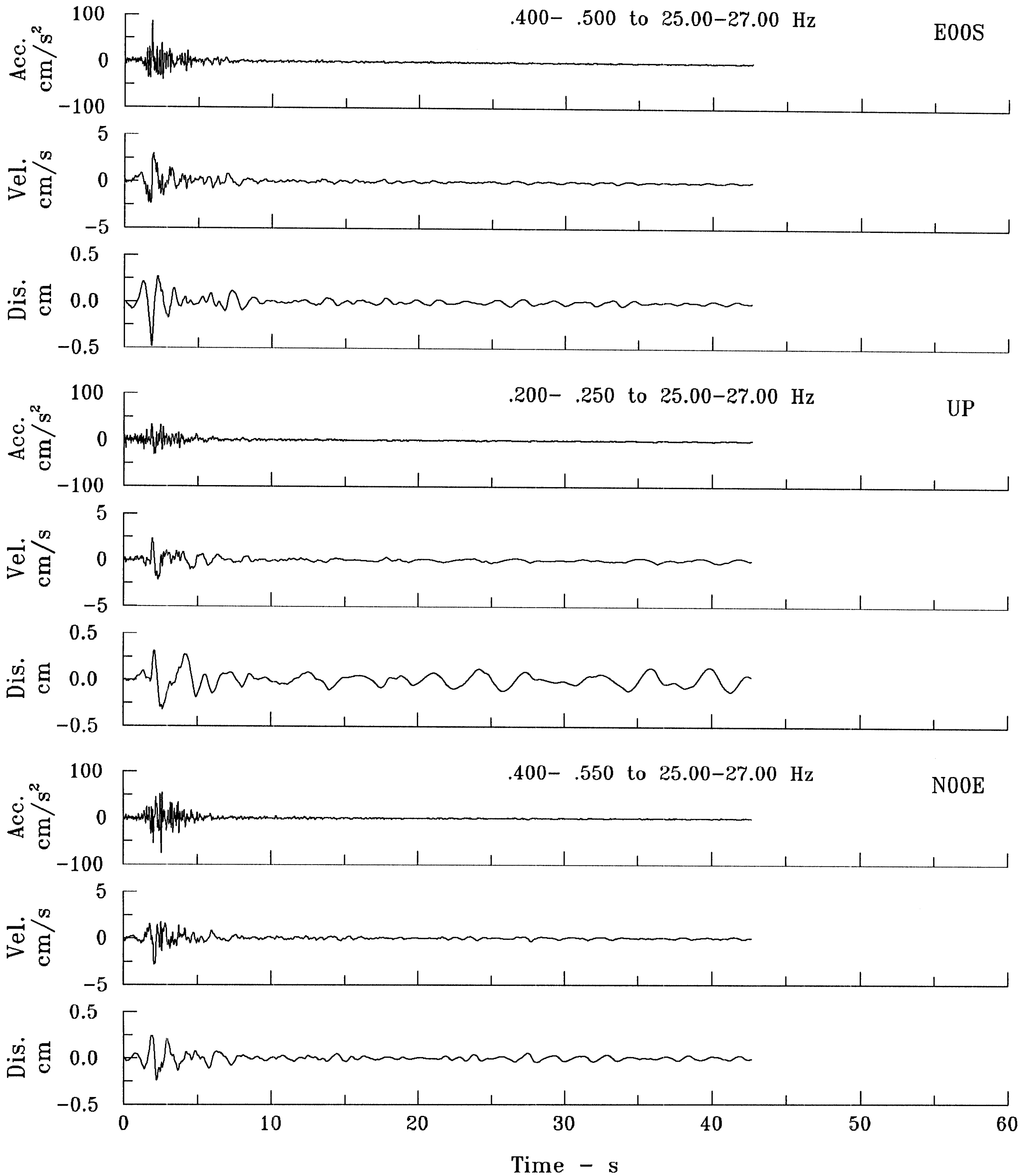


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 336) JAN 29, 1994 -1120 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 14.94 KM

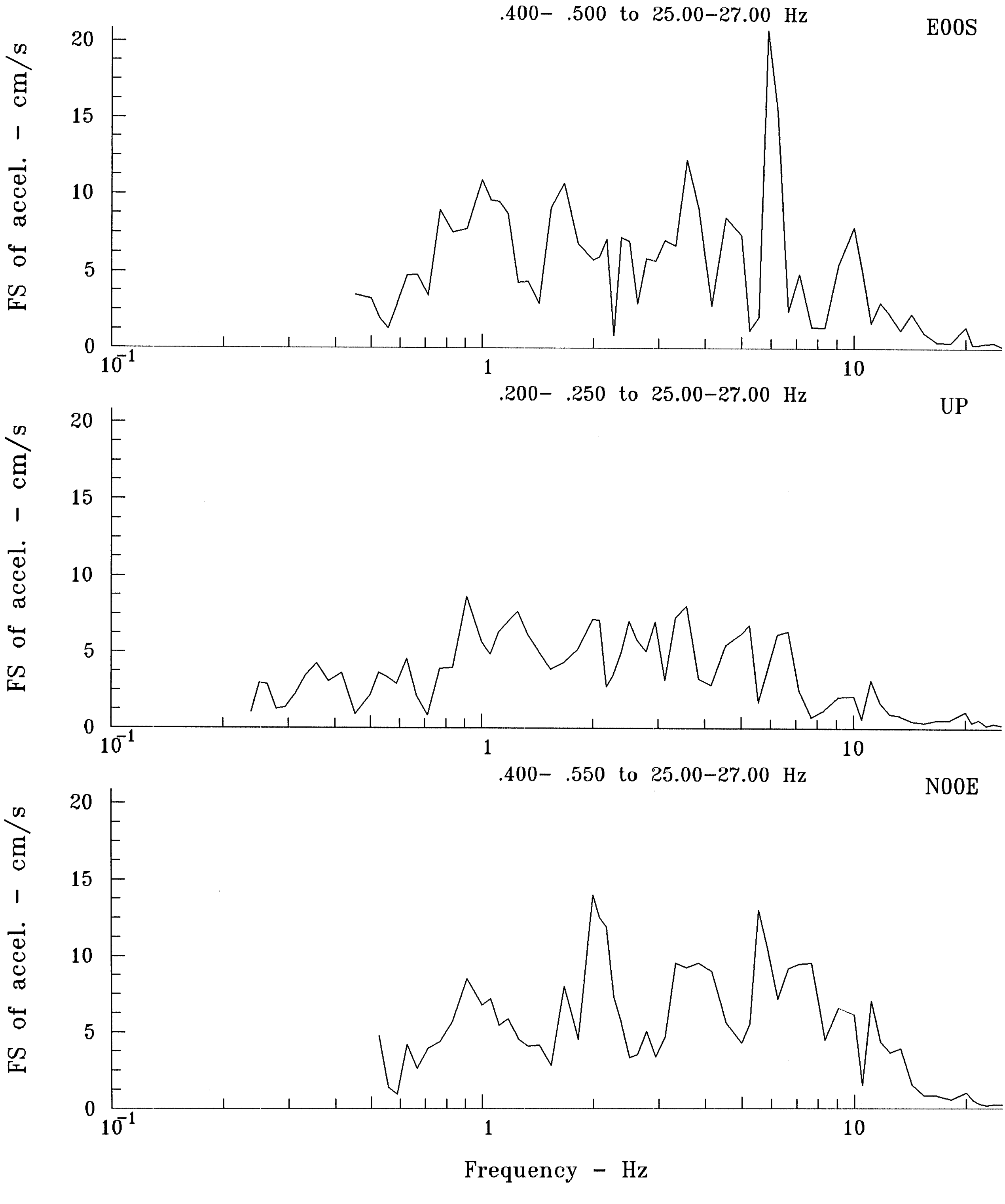


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 336) JAN 29, 1994 -1120 GMT

MAGNITUDE = 5.1 EPICENTRAL DISTANCE = 14.94 KM

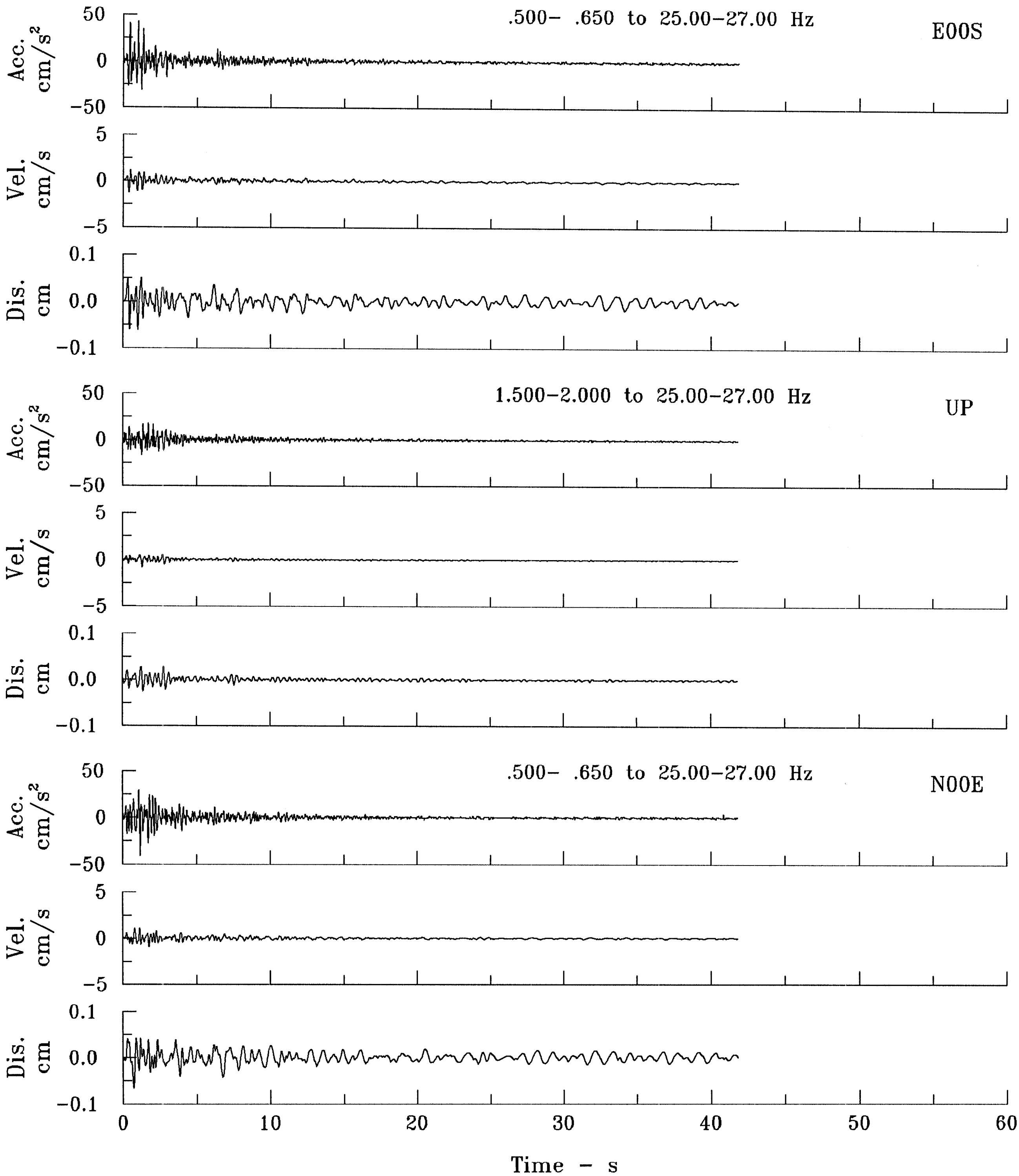


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 392) MAR 20, 1994 -2120 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 21.80 KM

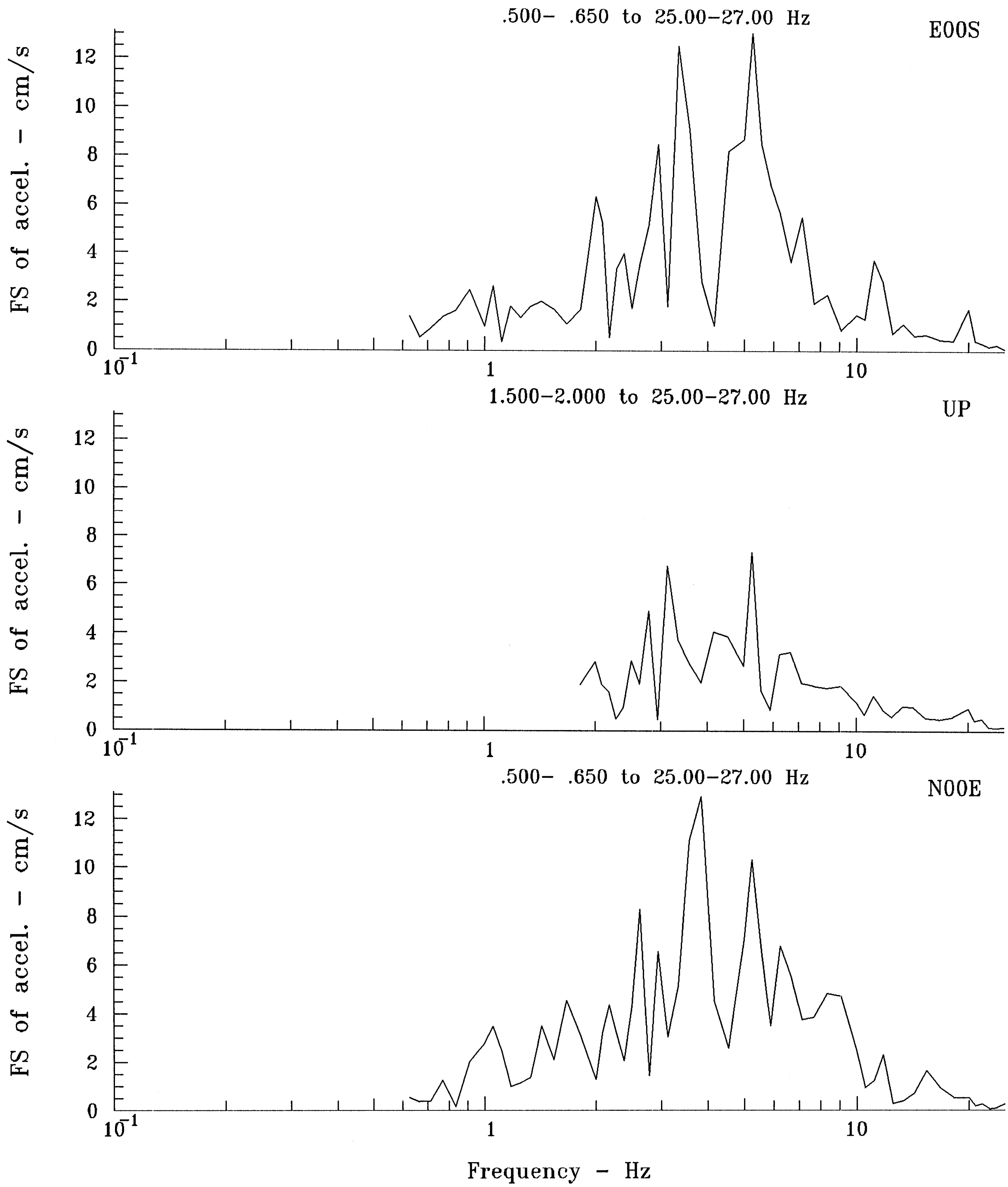


STATION USGS 5108 34.230 N, 118.712 W SMA-1 1277

SANTA SUSANA, ETEC Bldg #462 (Ground Floor)

NORTHRIDGE EARTHQUAKE (aft. 392) MAR 20, 1994 -2120 GMT

MAGNITUDE = 5.2 EPICENTRAL DISTANCE = 21.80 KM



Appendix A.5450

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

Table A.5450.1 List of processed records

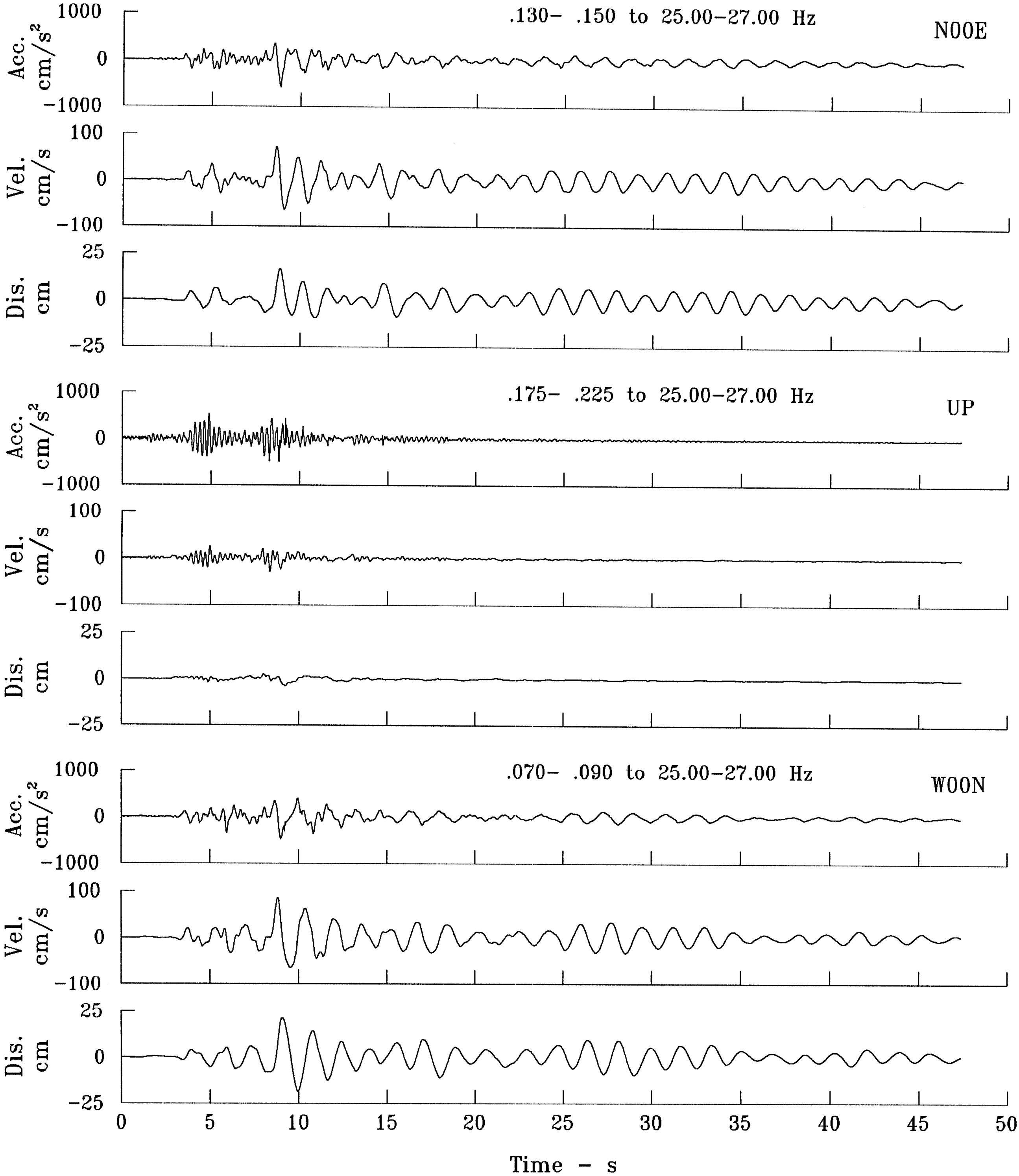
USGS: 5450 SMA-1 6146	BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)					34.152°N 118.337°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp.	Peak Acc. [g]
v1x0000.dat	IAA000	94.000.0	NORTHRIDGE EARTHQUAKE	19.6	47.4	N00E	0.644
						UP	1.060
						W00N	0.508
v1x0001.dat	IAA001	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	21.4	21.9	N00E	0.069
						UP	0.065
						W00N	0.085
v1x0005.dat	IAA005	94.000.5	NORTHRIDGE EARTHQUAKE (aft. -5)	21.4	16.3	N00E	0.024
						UP	0.031
						W00N	0.027
v1x0013.dat	IAA013	94.001.3	NORTHRIDGE EARTHQUAKE (aft. -13)	21.4	21.8	N00E	0.036
						UP	0.041
						W00N	0.031
v1x0014.dat	IAA014	94.001.4	NORTHRIDGE EARTHQUAKE (aft. -14)	21.4	11.6	N00E	0.020
						UP	0.014
						W00N	0.011

STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 19.61 KM

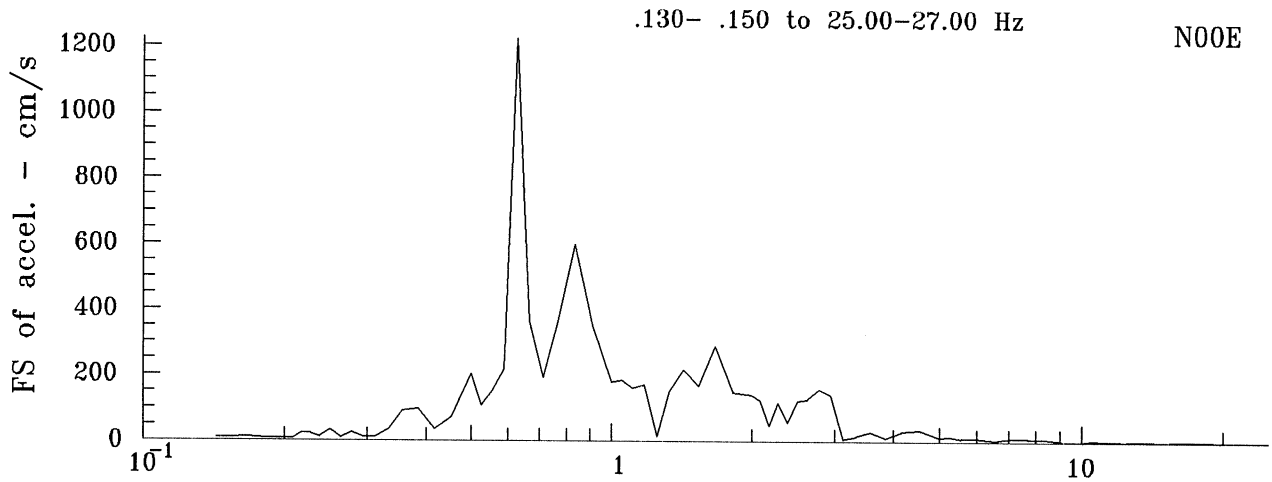


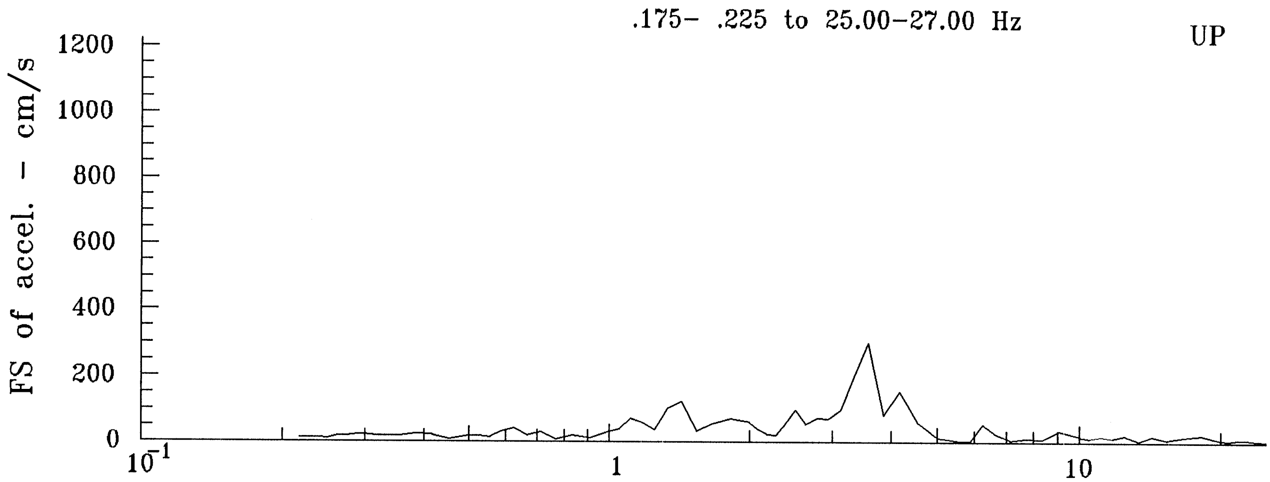
STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

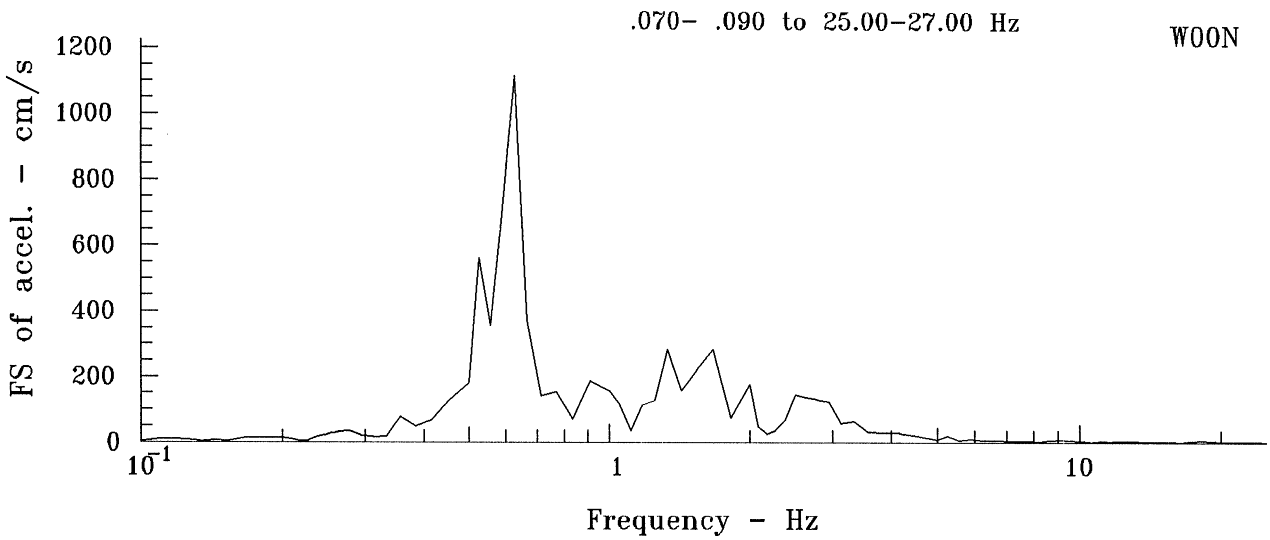
BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 19.61 KM





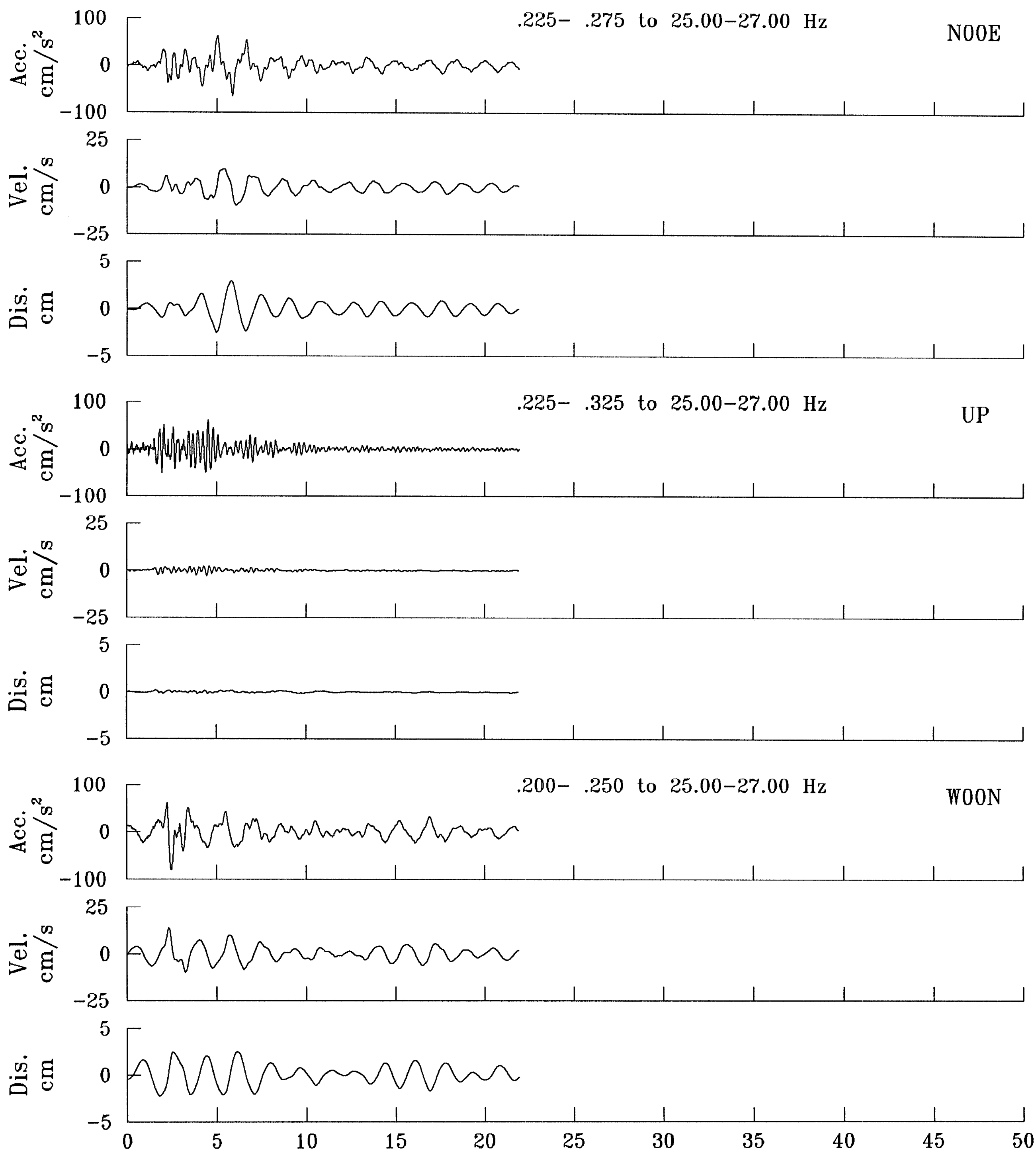


STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 21.40 KM

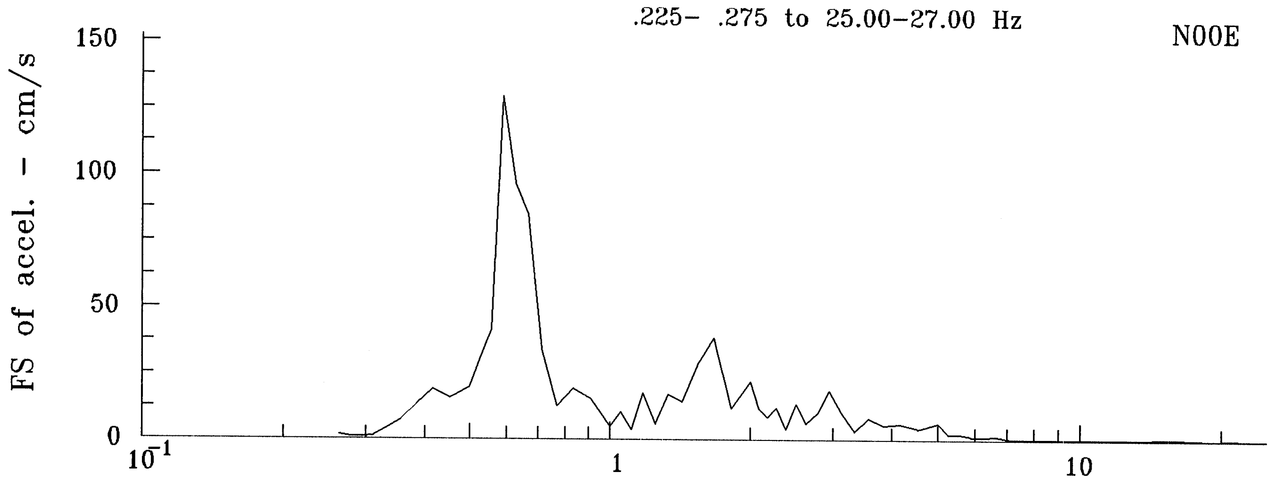


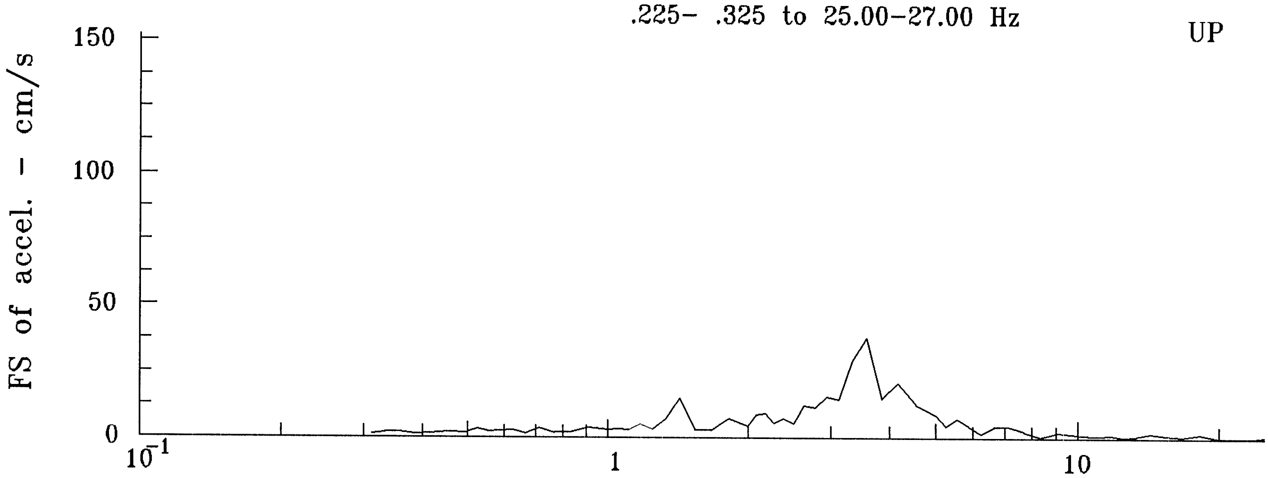
STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

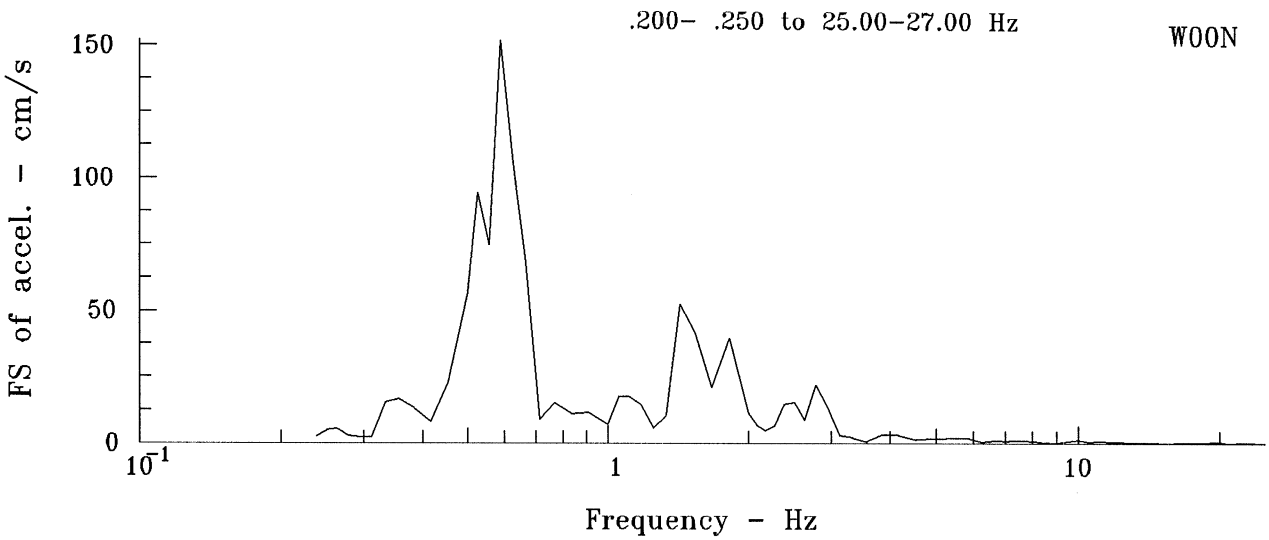
BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 21.40 KM





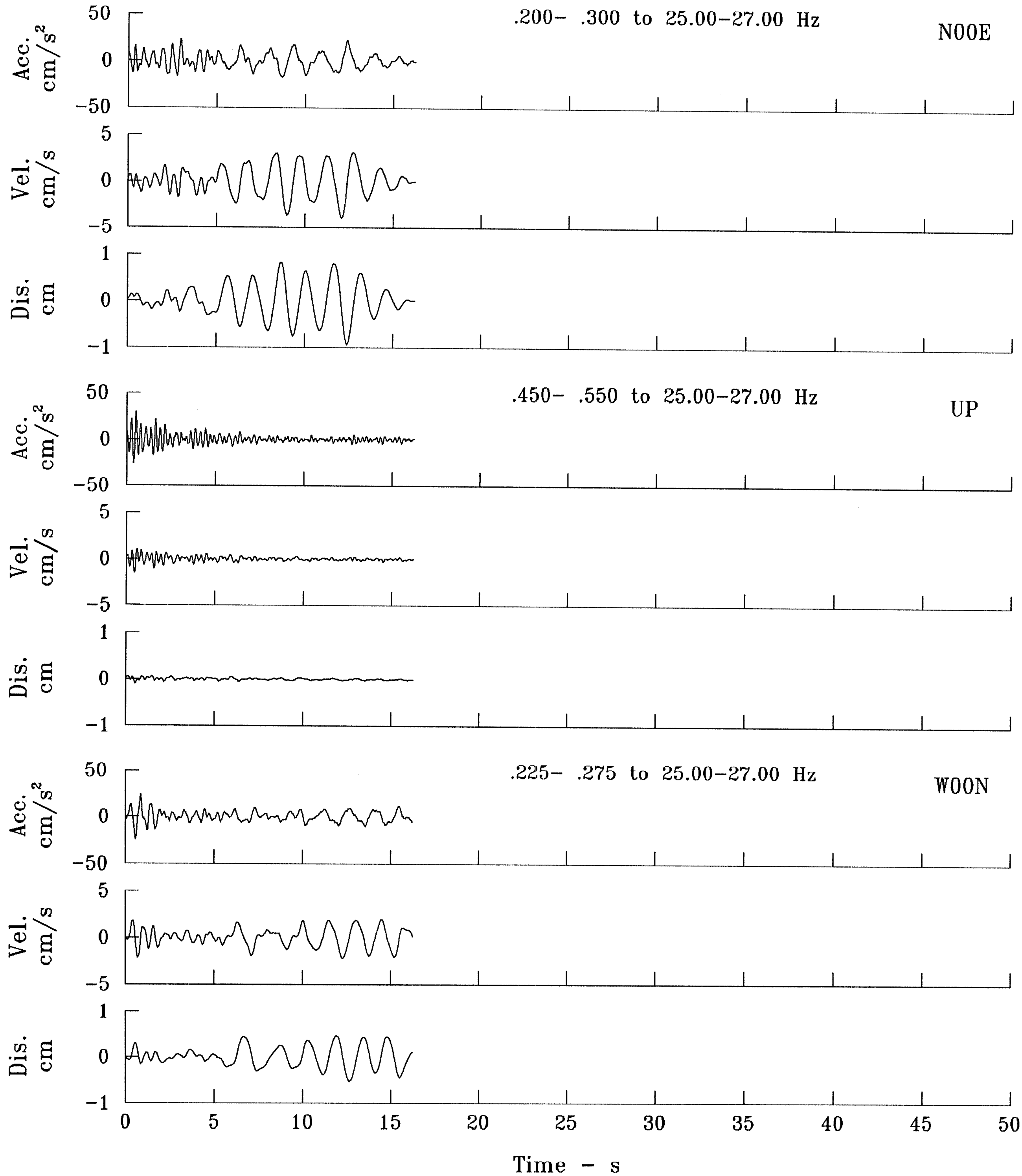


STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -5) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 21.40 KM

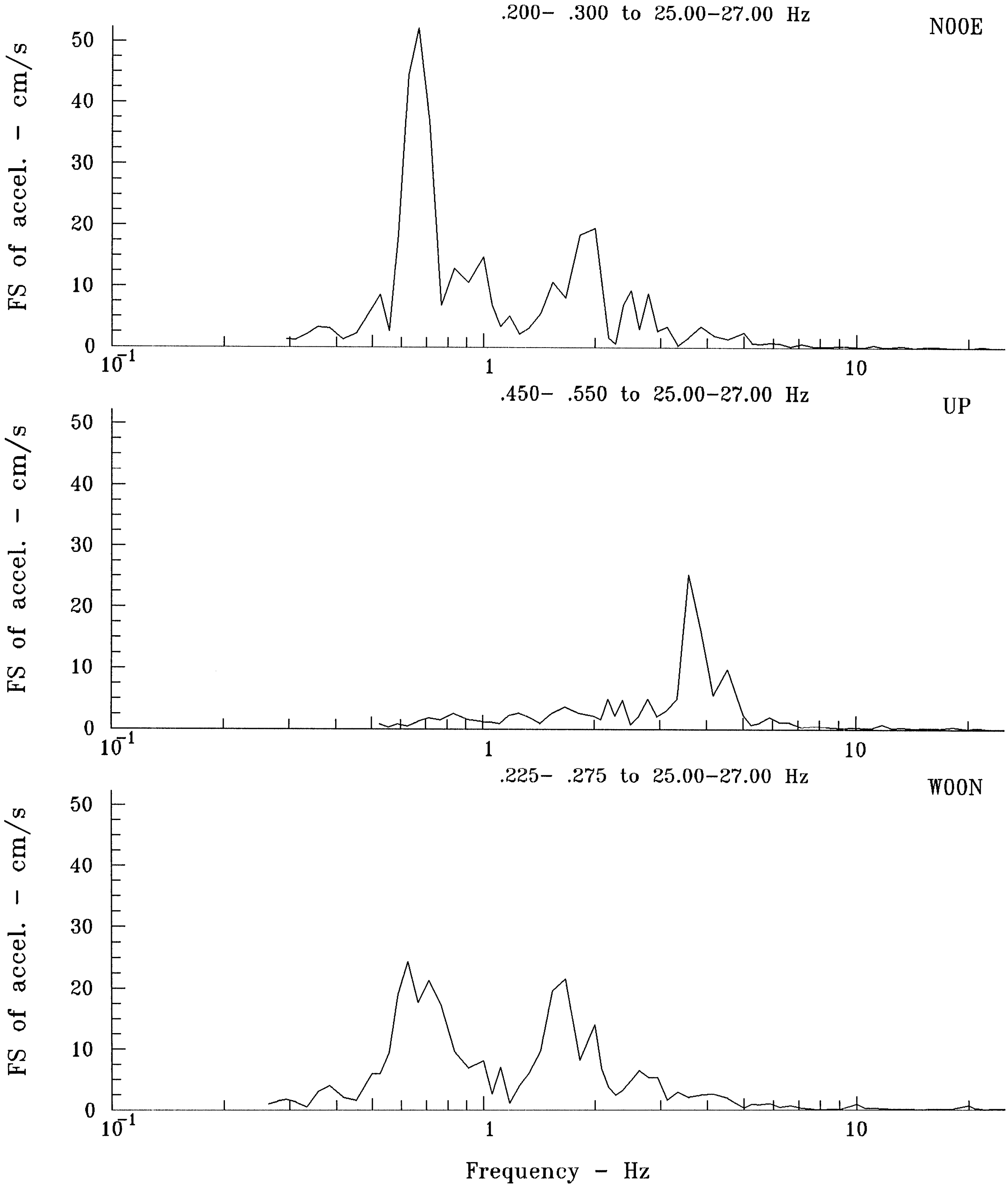


STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -5) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 21.40 KM

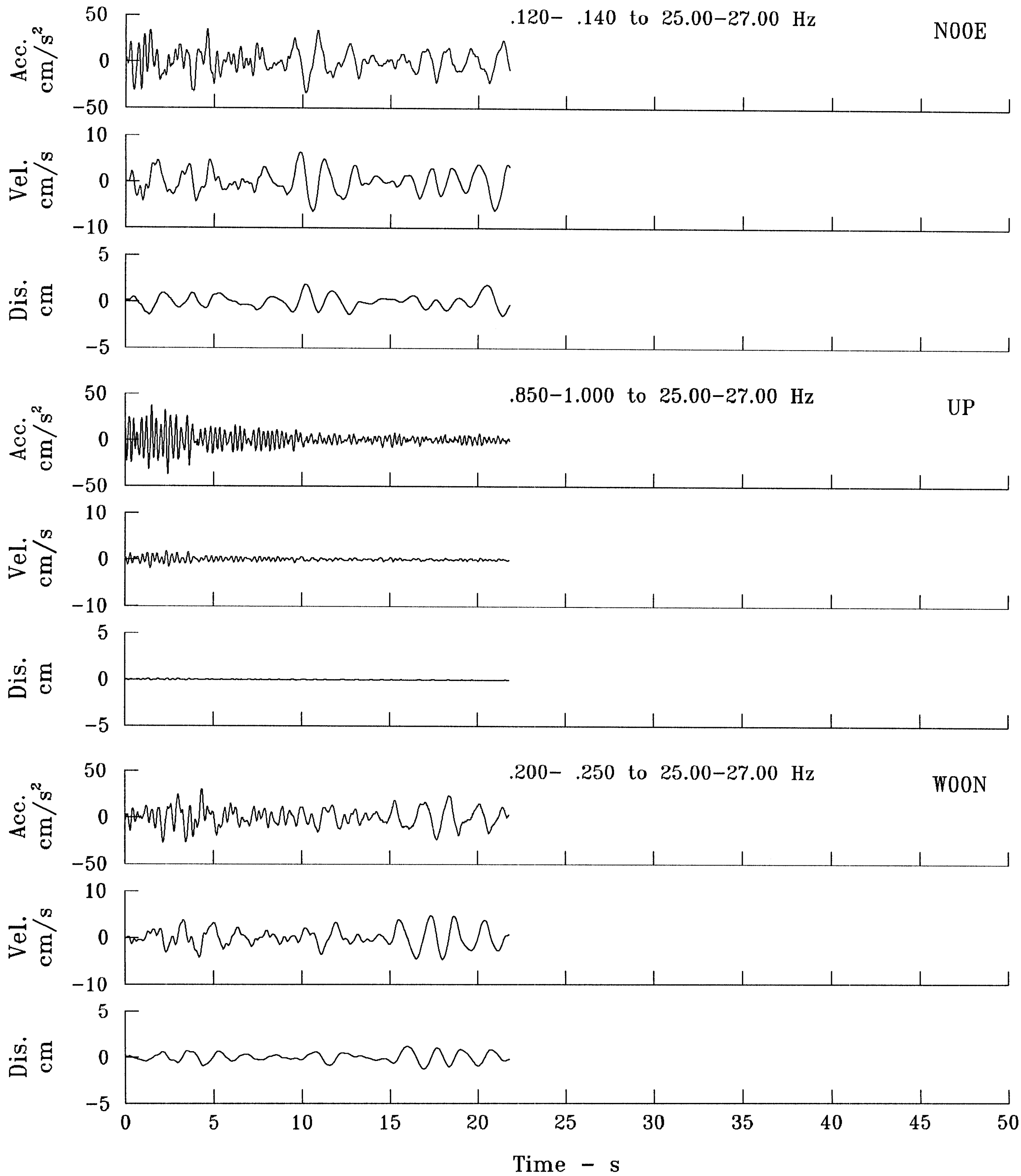


STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -13) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 21.40 KM

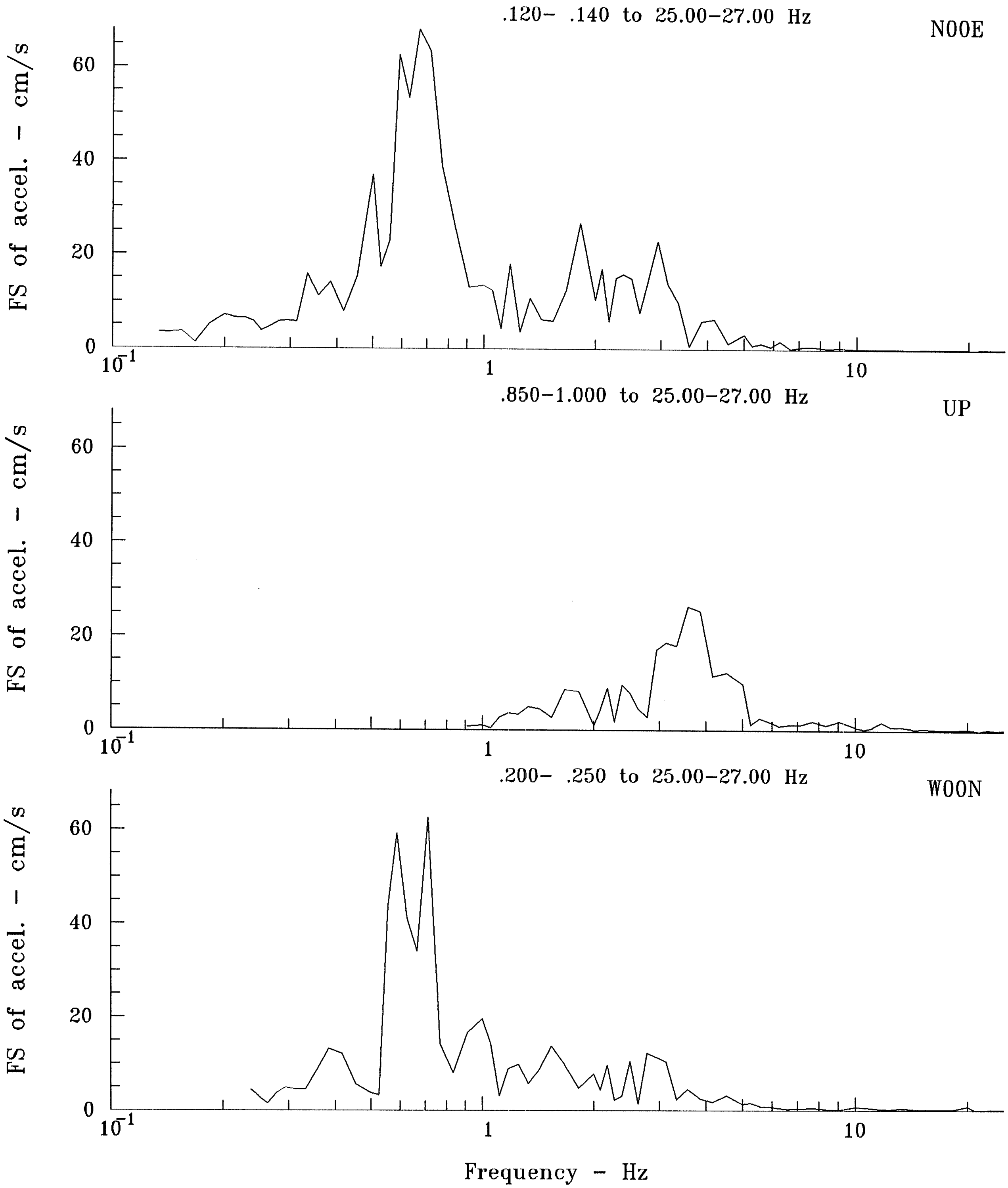


STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -13) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 21.40 KM

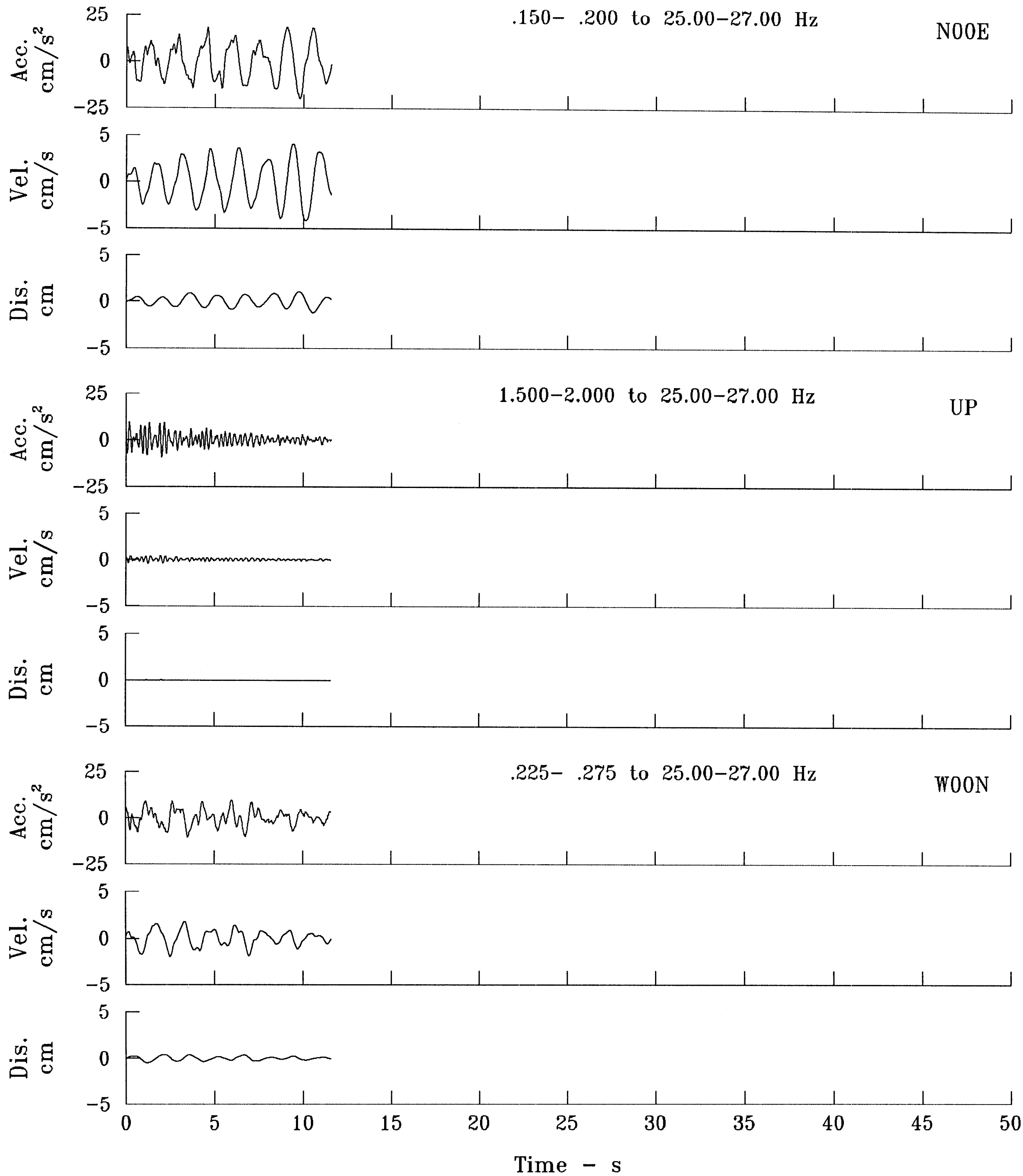


STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -14) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 21.40 KM

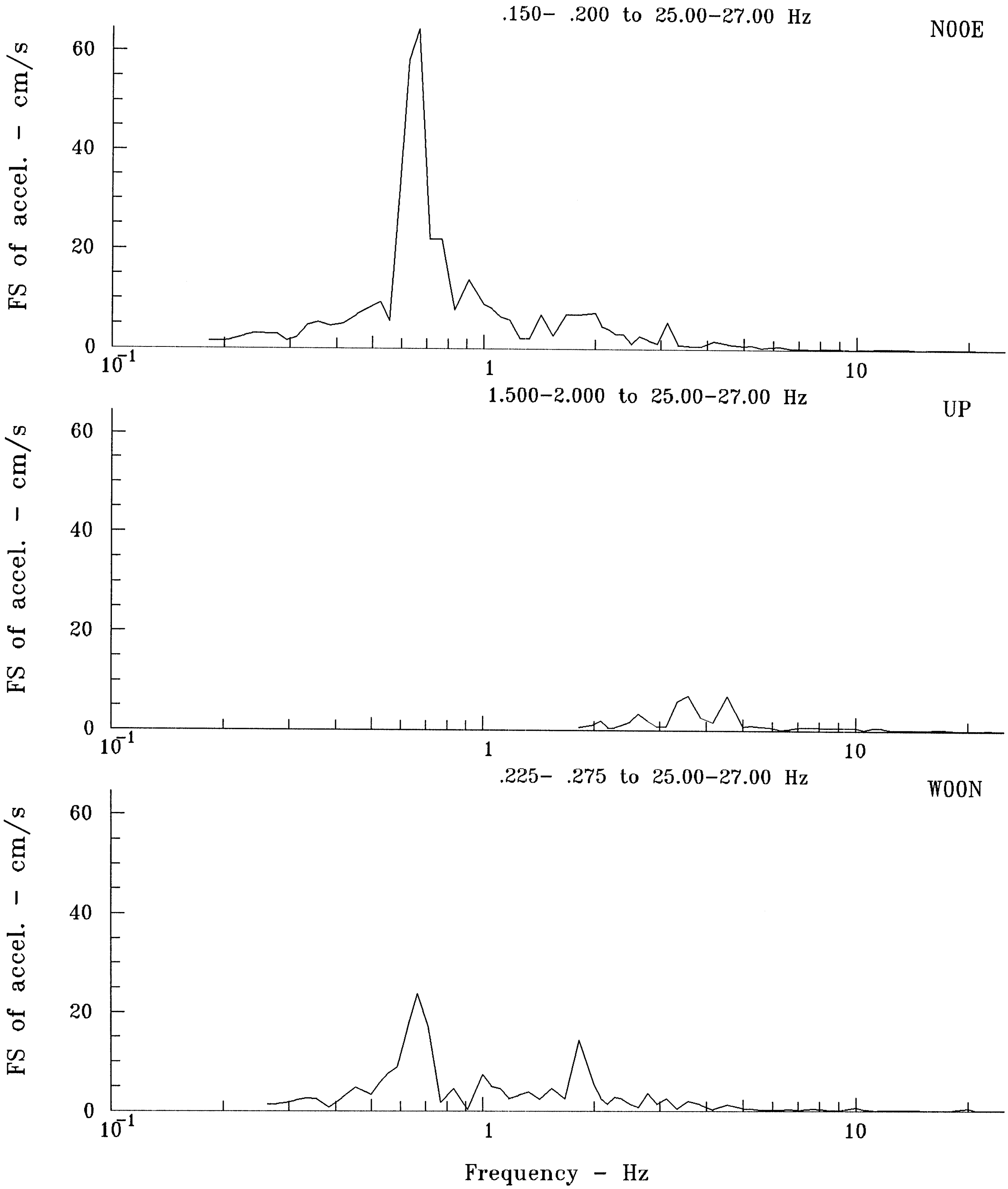


STATION USGS 5450 34.152 N, 118.337 W SMA-1 6146

BURBANK, 3601 WEST OLIVE AVE., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -14) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 21.40 KM



Appendix A.5451

LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)

Table A.5451.1 List of processed records

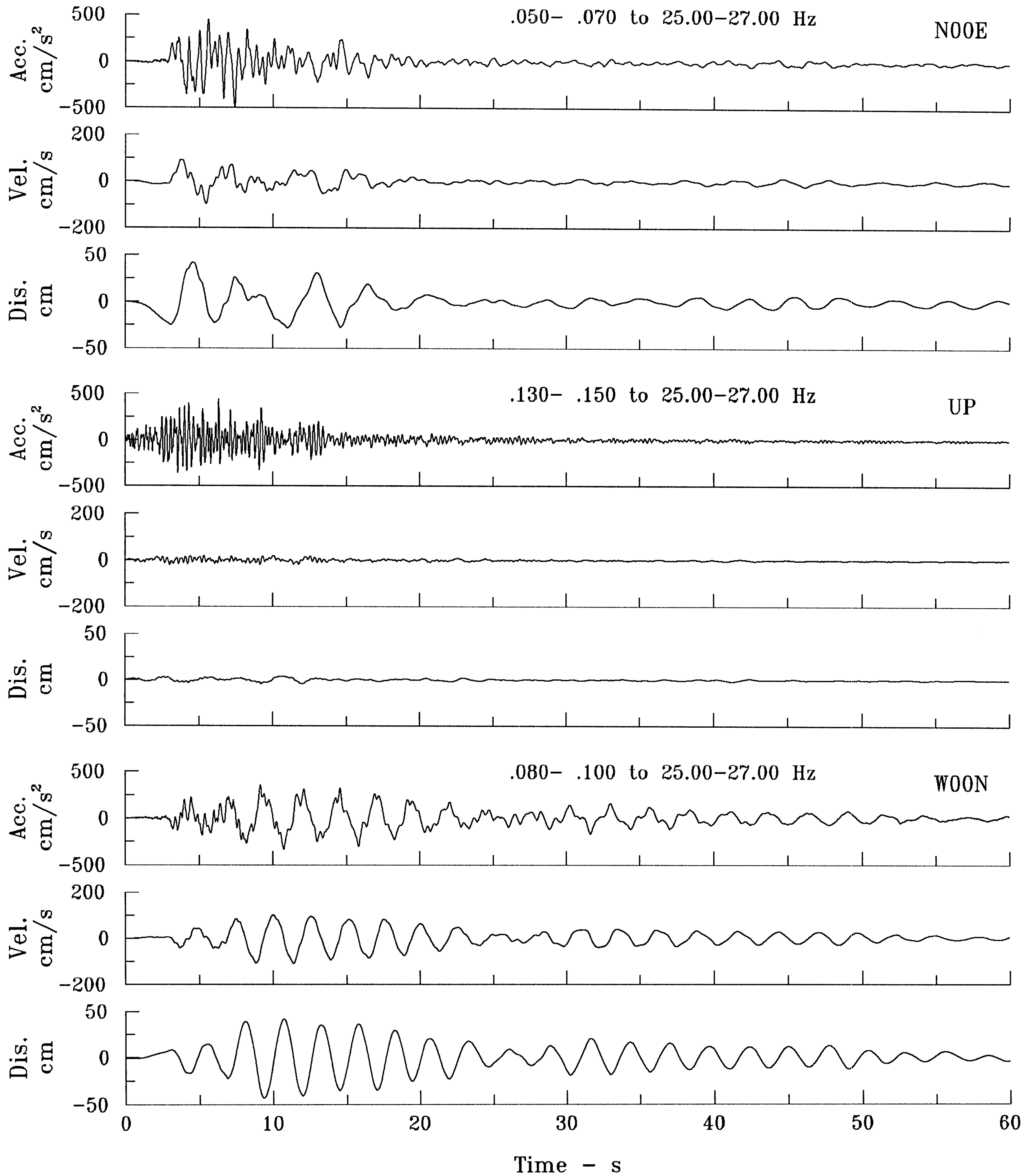
USGS: 5451 SMA-1 4048	LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)					34.185°N 118.584°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp.	Peak Acc. [g]
v1x0000.dat	IAA000	94.000.0	NORTHRIDGE EARTHQUAKE	5.4	99.2	N00E	0.552
						UP	0.477
						W00N	0.373
v1x0026.dat	IAA026	94.002.6	NORTHRIDGE EARTHQUAKE (aft. -26)	15.55	41.5	N00E	0.077
						UP	0.068
						W00N	0.073
v1x0115.dat	IAA115	94.011.5	NORTHRIDGE EARTHQUAKE (aft. -115)	15.55	38.3	N00E	0.034
						UP	0.090
						W00N	0.045

STATION USGS 5451 34.185 N, 118.584 W SMA-1 4048

LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 5.43 KM

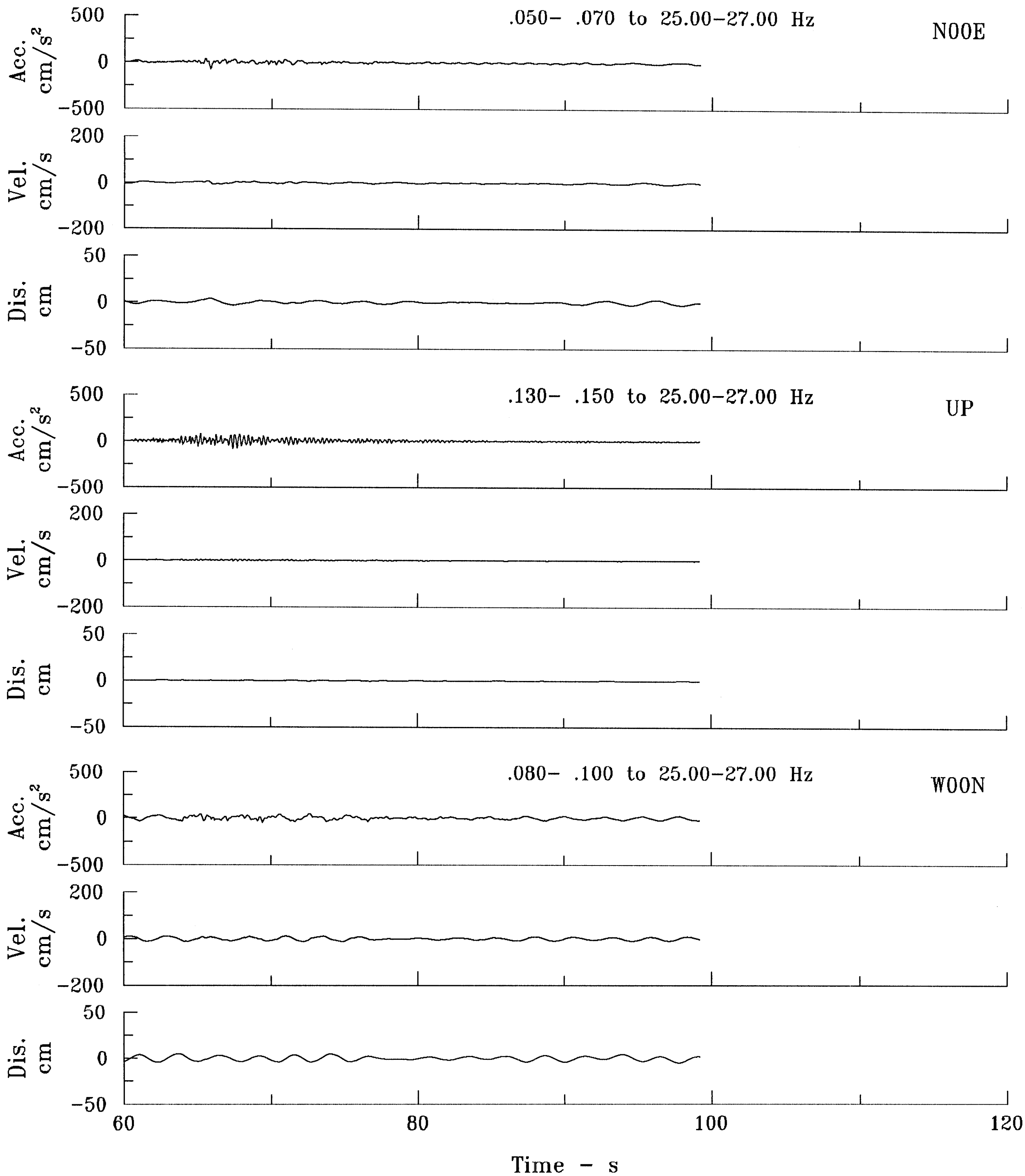


STATION USGS 5451 34.185 N, 118.584 W SMA-1 4048

LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 5.43 KM

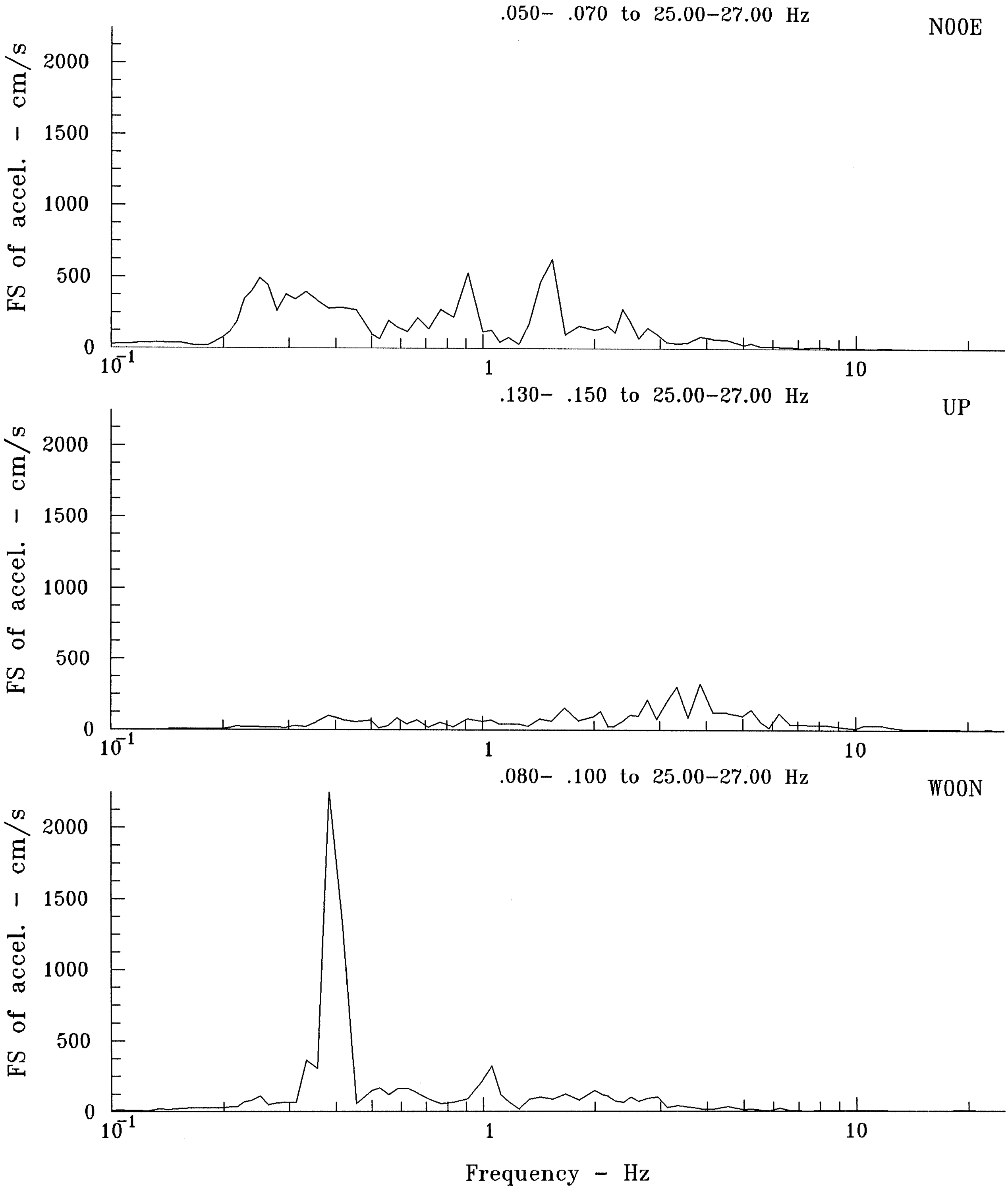


STATION USGS 5451 34.185 N, 118.584 W SMA-1 4048

LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 5.43 KM

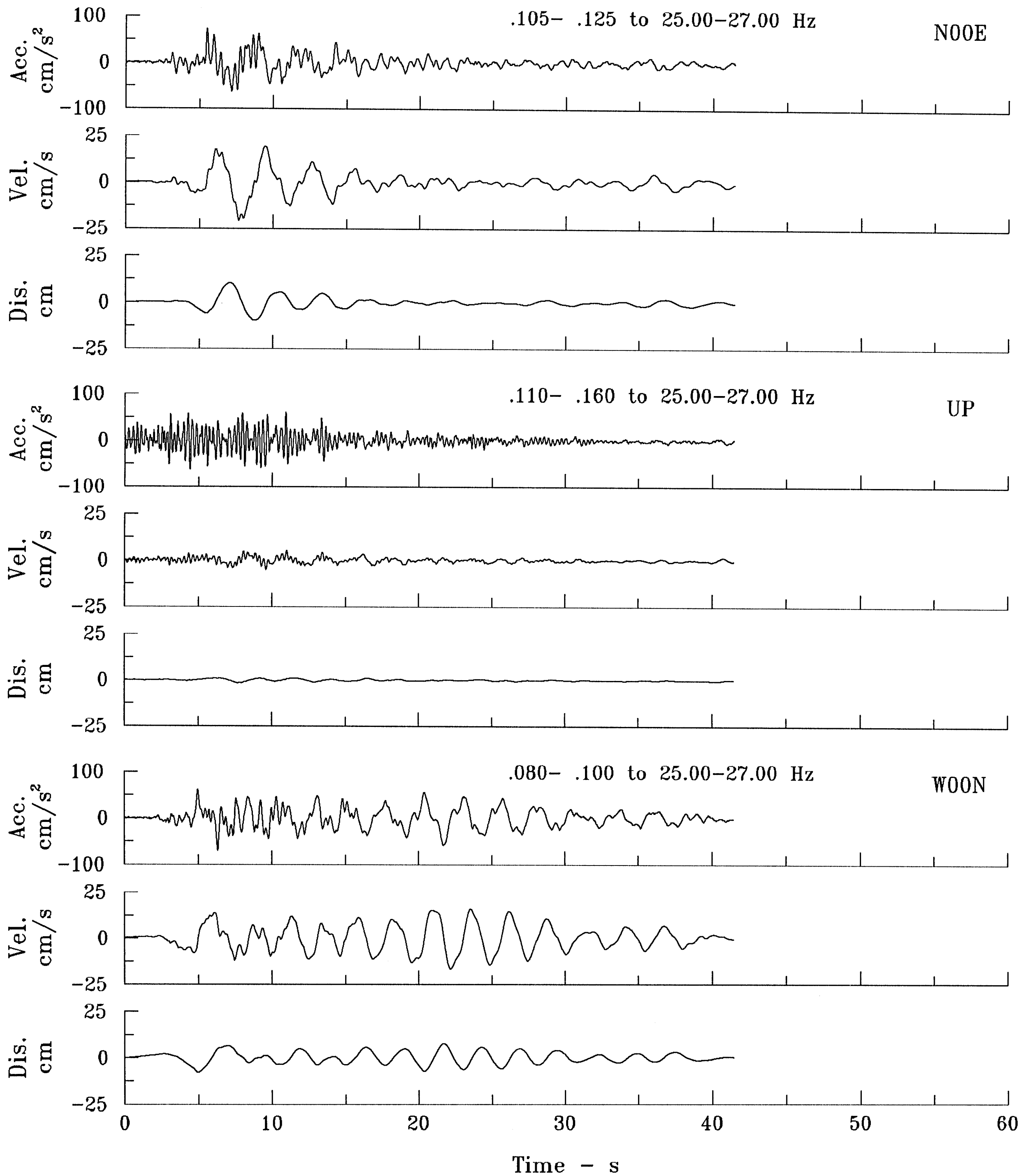


STATION USGS 5451 34.185 N, 118.584 W SMA-1 4048

LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)

NORTHRIDGE EARTHQUAKE (aft. -26) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.55 KM

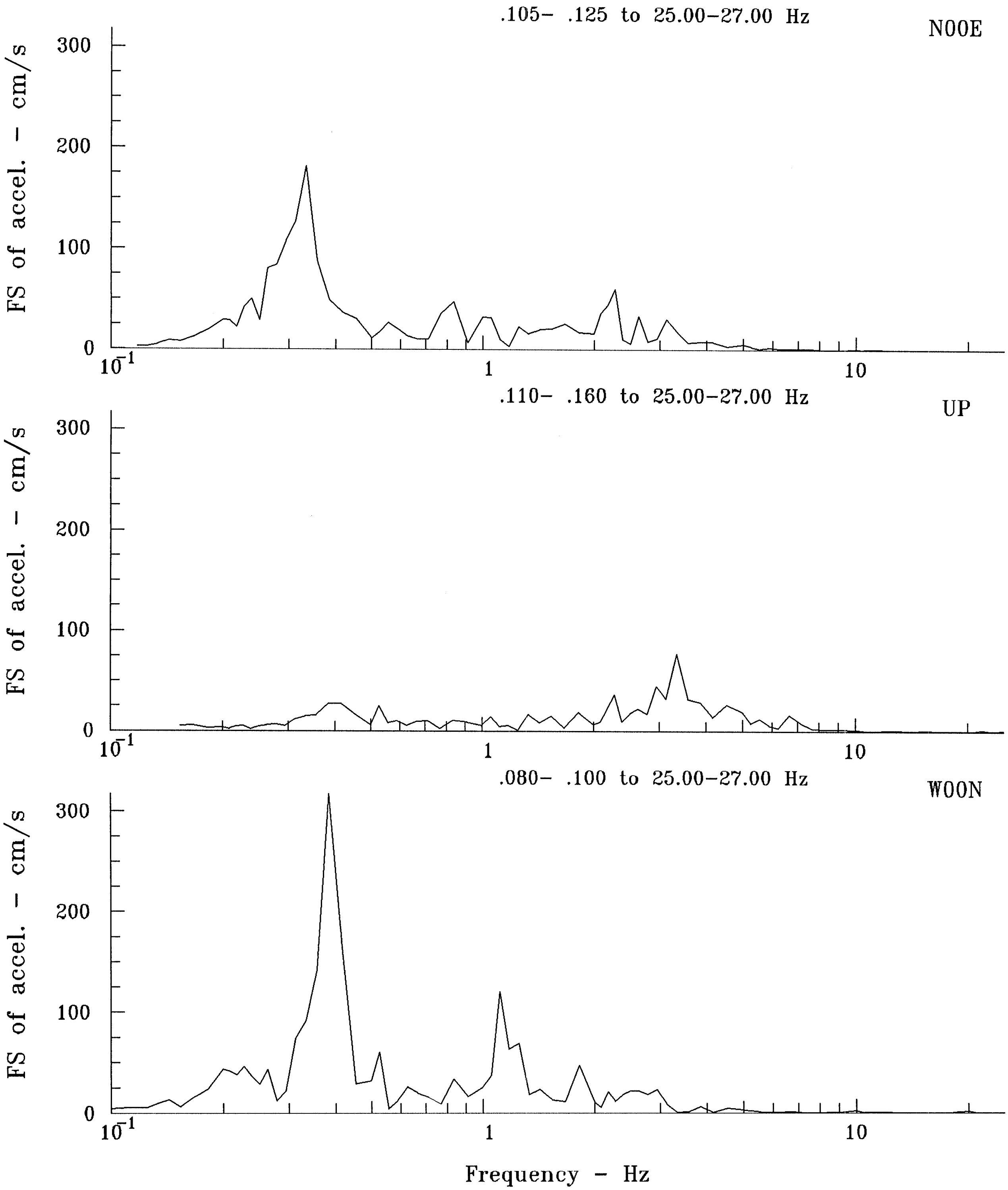


STATION USGS 5451 34.185 N, 118.584 W SMA-1 4048

LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)

NORTHRIDGE EARTHQUAKE (aft. -26) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.55 KM

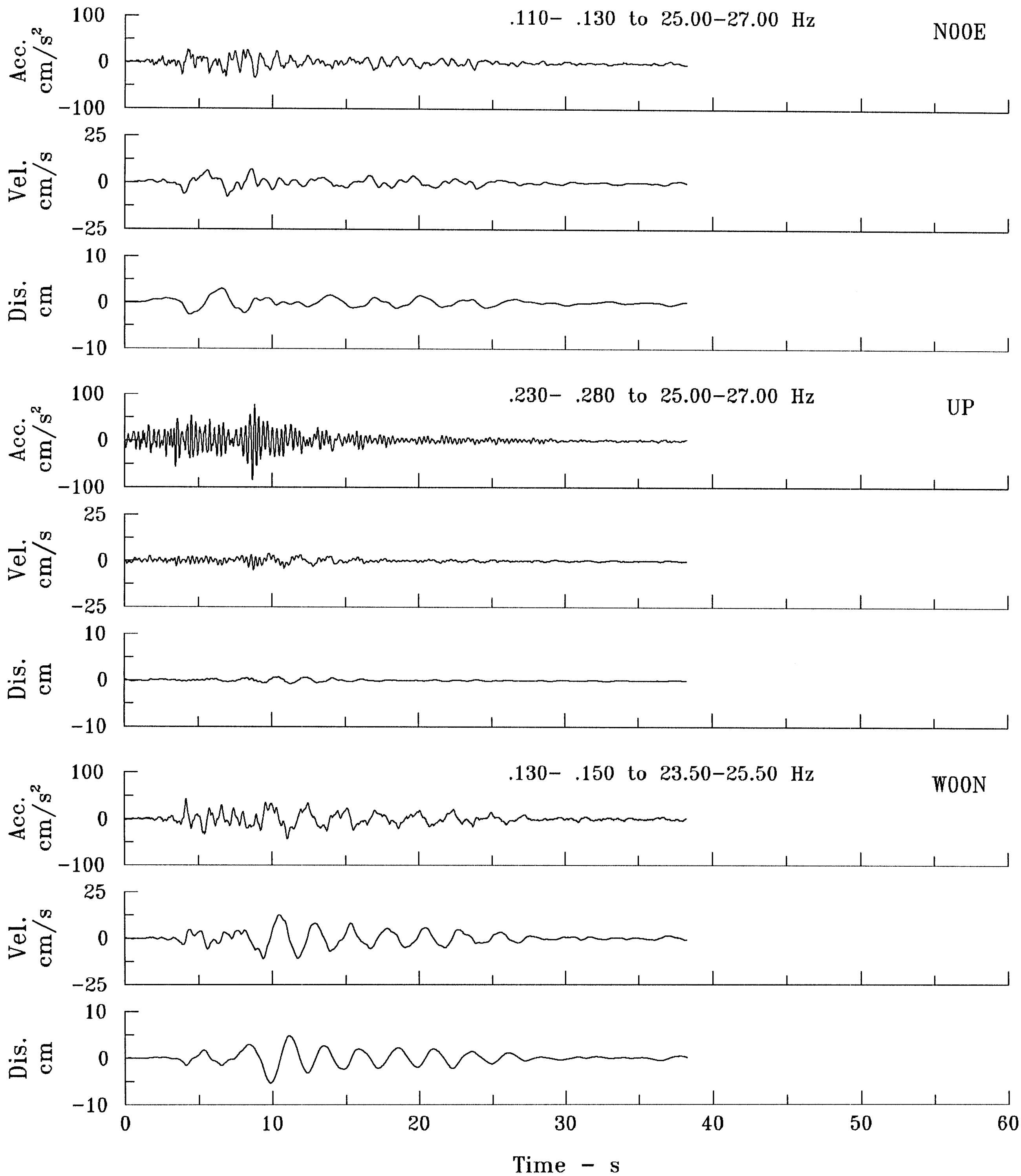


STATION USGS 5451 34.185 N, 118.584 W SMA-1 4048

LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)

NORTHRIDGE EARTHQUAKE (aft. -115) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.55 KM

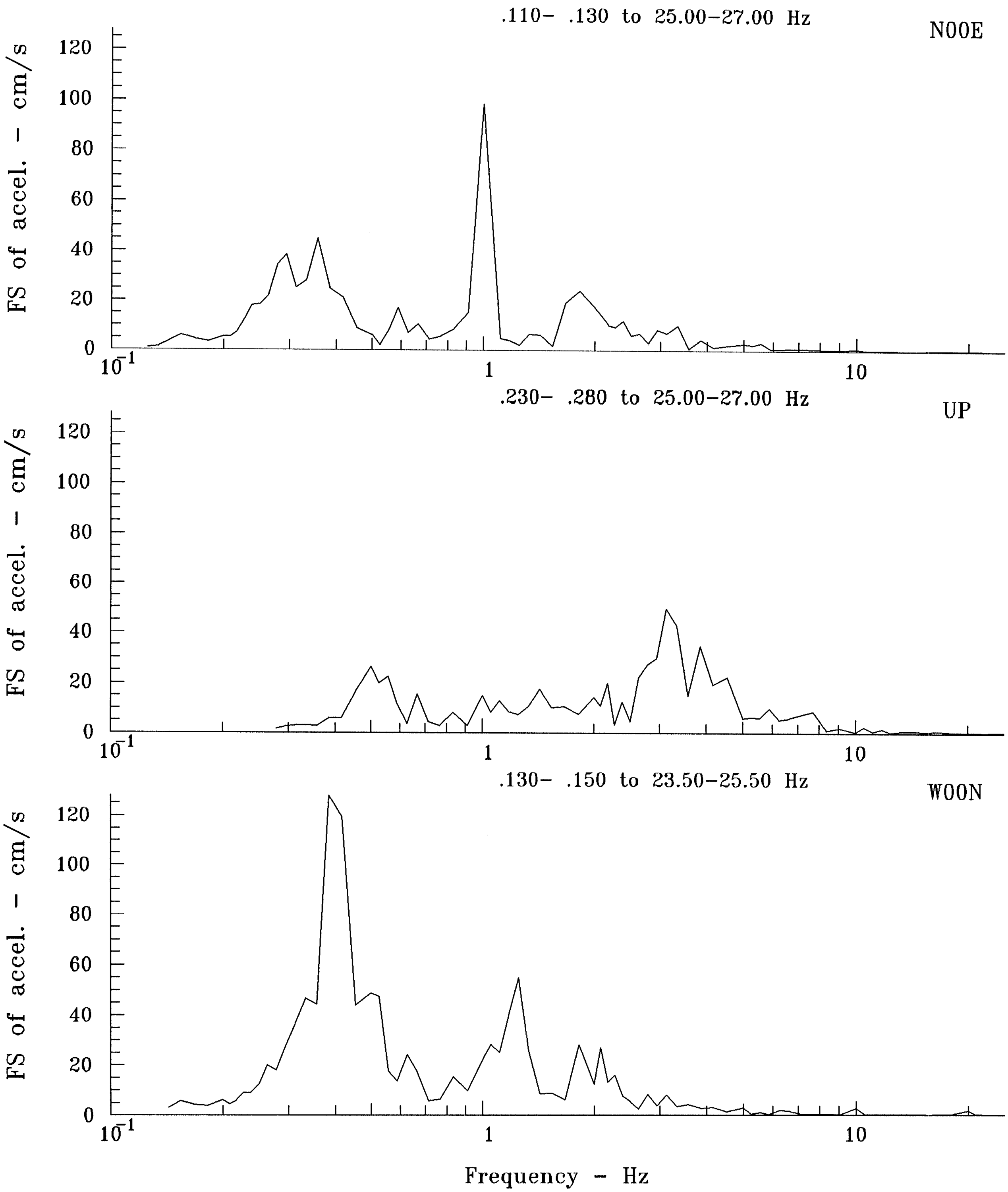


STATION USGS 5451 34.185 N, 118.584 W SMA-1 4048

LOS ANGELES, 6301 OWENSMOUTH AVE., ROOF (12th level)

NORTHRIDGE EARTHQUAKE (aft. -115) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.55 KM



Appendix A.5453

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

Table A.5453.1 List of processed records

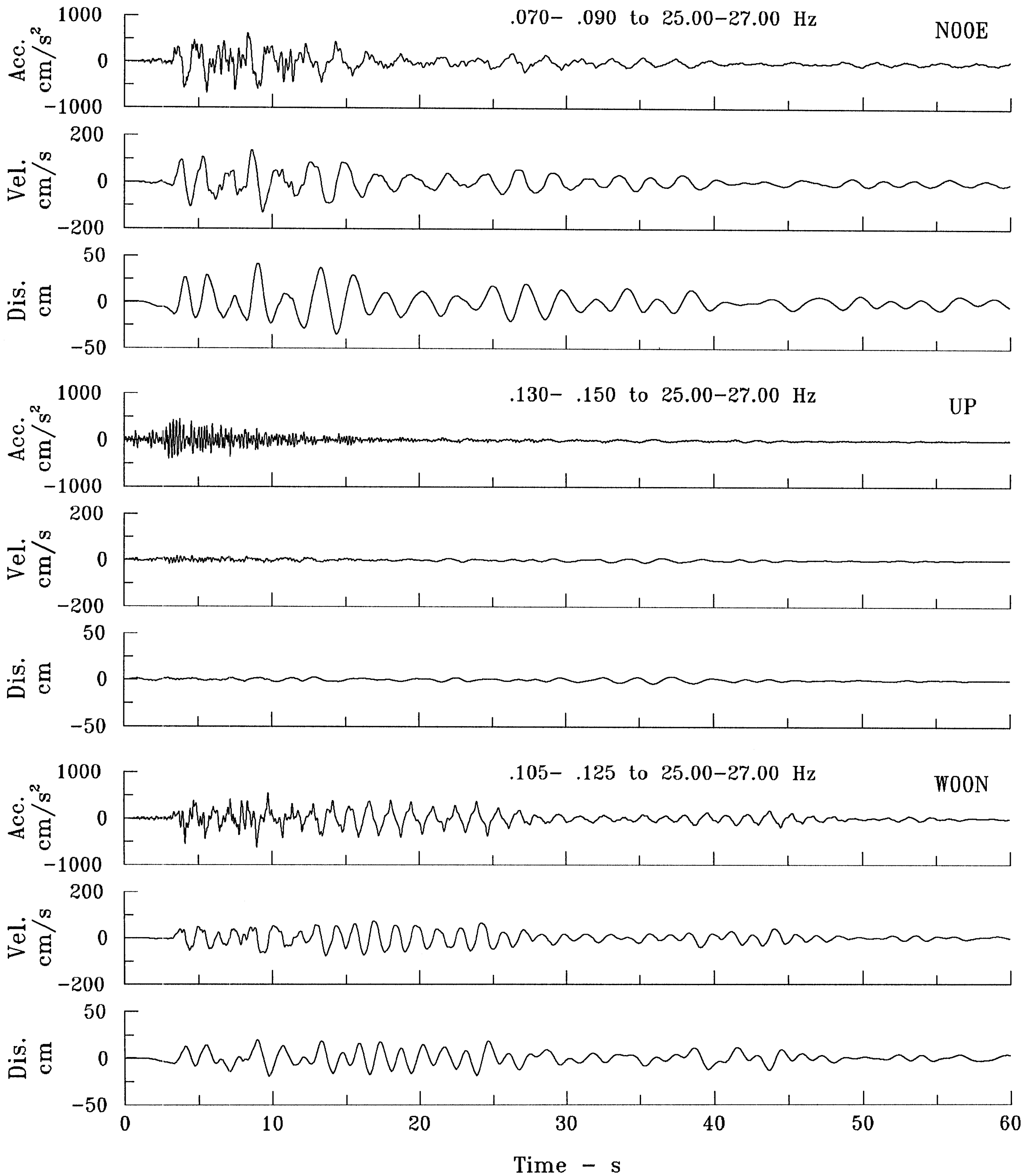
USGS: 5453 SMA-1 7073	LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)					34.175°N 118.465°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp.	Peak Acc. [g]
v1X0000.DAT	IAA034	94.000.0	NORTHRIDGE EARTHQUAKE	7.9	60.9	N00E	0.735
						UP	0.488
						W00N	0.663
v1X0001.DAT	IAA034	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	14.0	30.6	N00E	0.231
						UP	0.104
						W00N	0.130
v1X0007.DAT	IAA034	94.000.7	NORTHRIDGE EARTHQUAKE (aft. -7)	14.0	18.1	N00E	0.026
						UP	0.015
						W00N	0.023
v1X0024.DAT	IAA034	94.002.4	NORTHRIDGE EARTHQUAKE (aft. -24)	14.0	21.1	N00E	0.040
						UP	0.021
						W00N	0.053
v1X0026.DAT	IAA034	94.002.6	NORTHRIDGE EARTHQUAKE (aft. -26)	14.0	23.2	N00E	0.057
						UP	0.047
						W00N	0.086
v1X0029.DAT	IAA034	94.002.9	NORTHRIDGE EARTHQUAKE (aft. -29)	14.0	23.2	N00E	0.041
						UP	0.017
						W00N	0.044
v1X0103.DAT	IAA103	94.010.3	NORTHRIDGE EARTHQUAKE (aft. -103)	14.0	24.5	N00E	0.045
						UP	0.017
						W00N	0.037
v1X0104.DAT	IAA104	94.010.4	NORTHRIDGE EARTHQUAKE (aft. -104)	14.0	19.1	N00E	0.017
						UP	0.015
						W00N	0.031
v1X0115.DAT	IAA115	94.011.5	NORTHRIDGE EARTHQUAKE (aft. -115)	14.0	26.9	N00E	0.055
						UP	0.019
						W00N	0.065

STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 7.90 KM

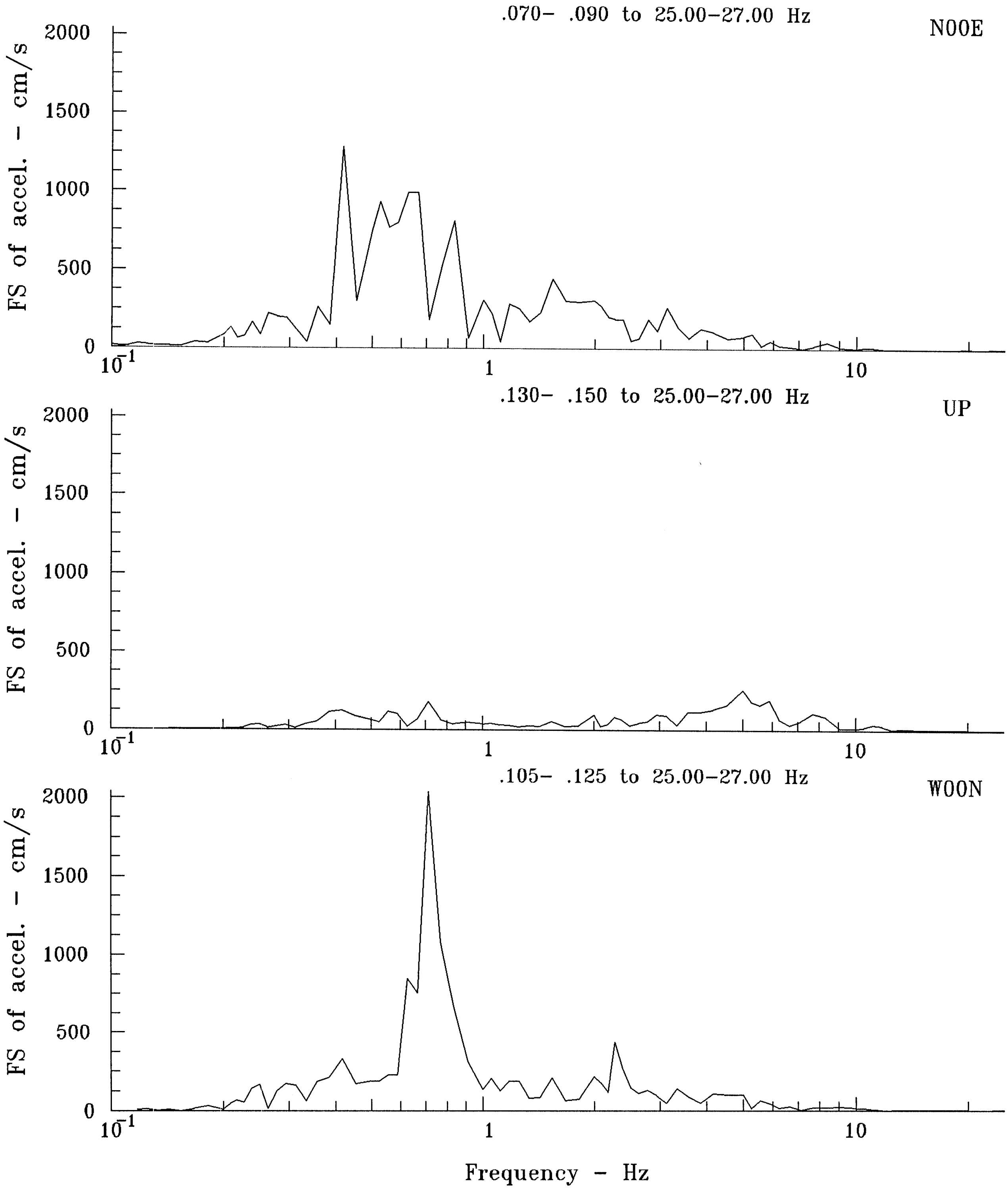


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 7.90 KM

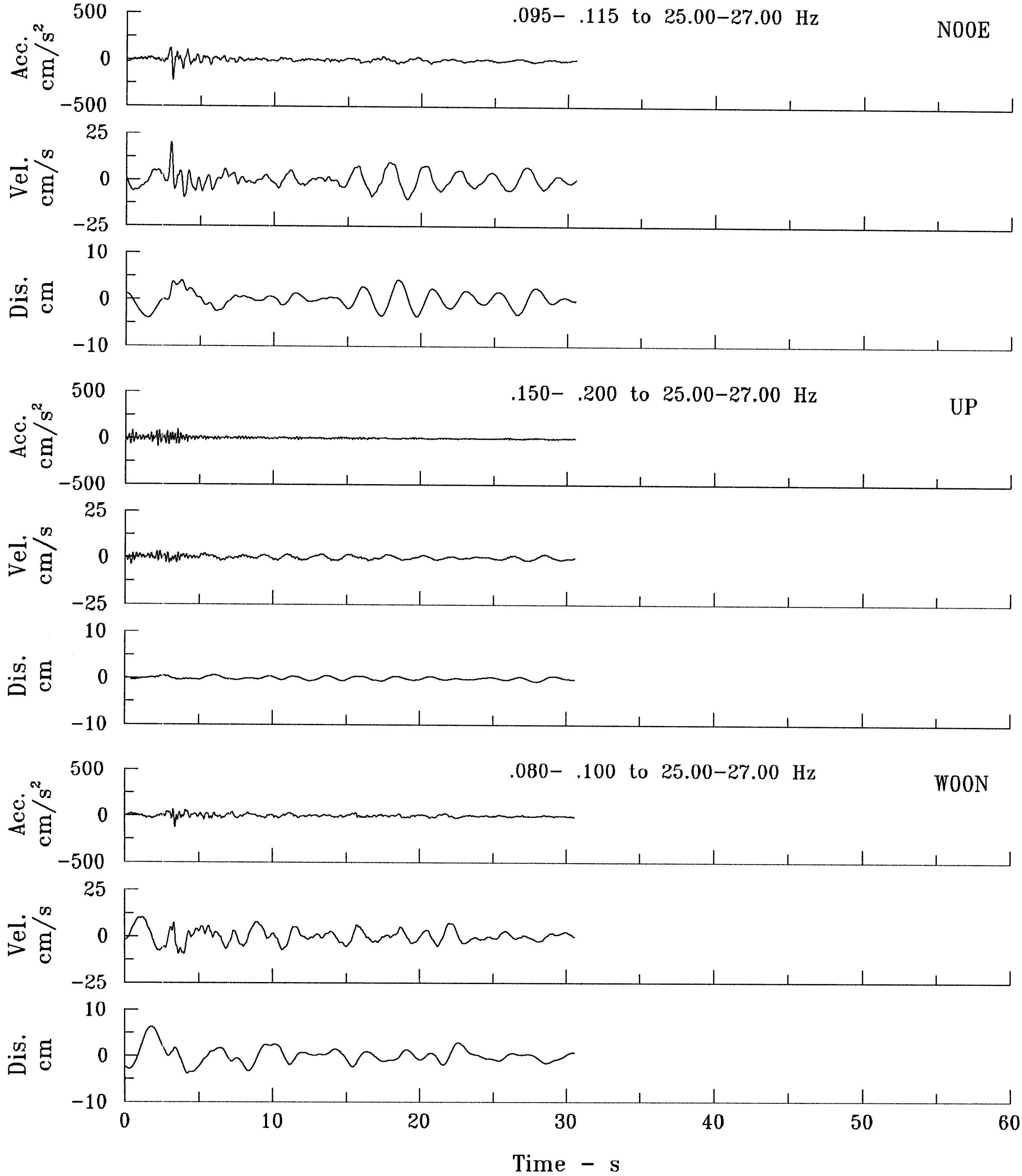


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

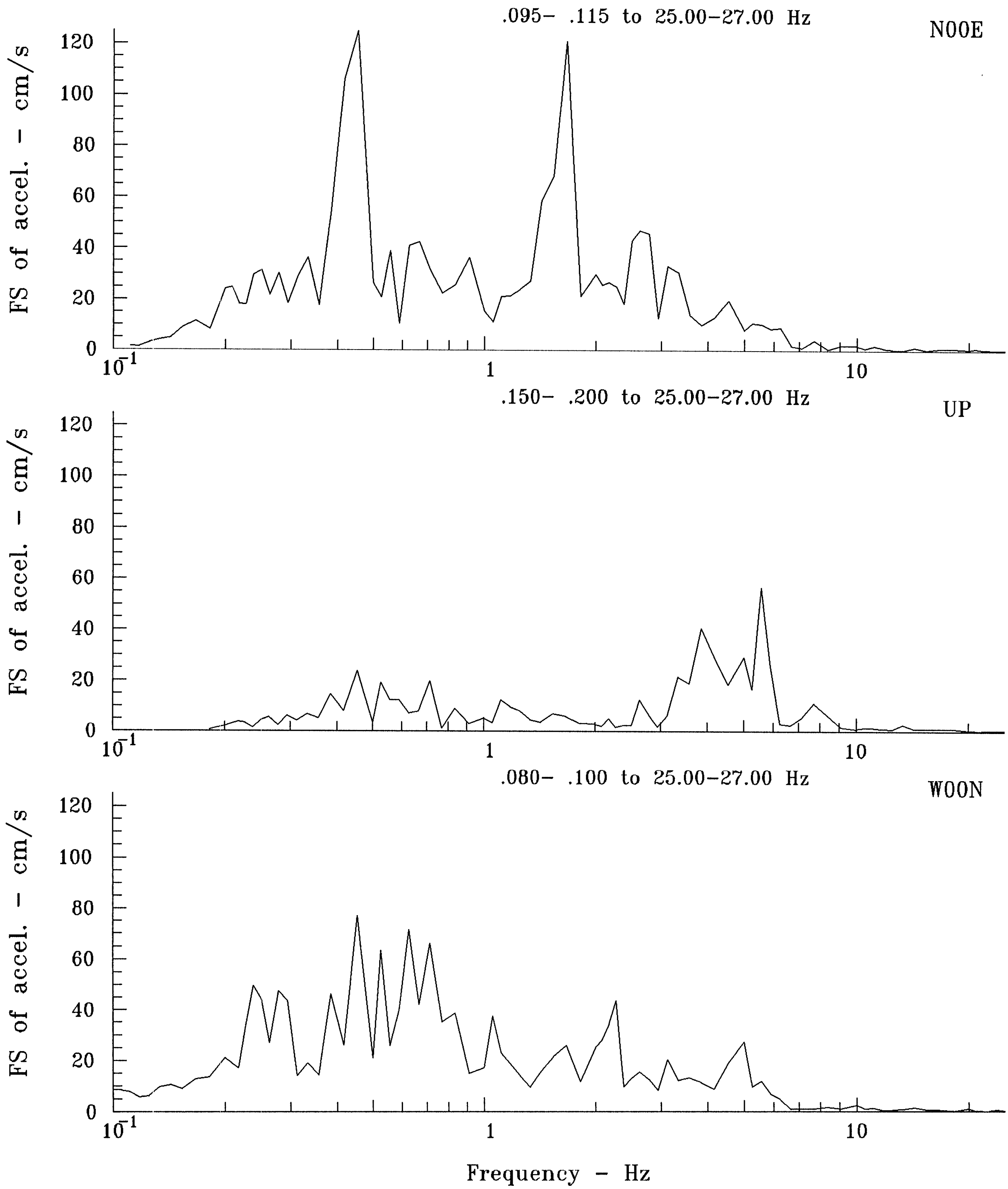


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

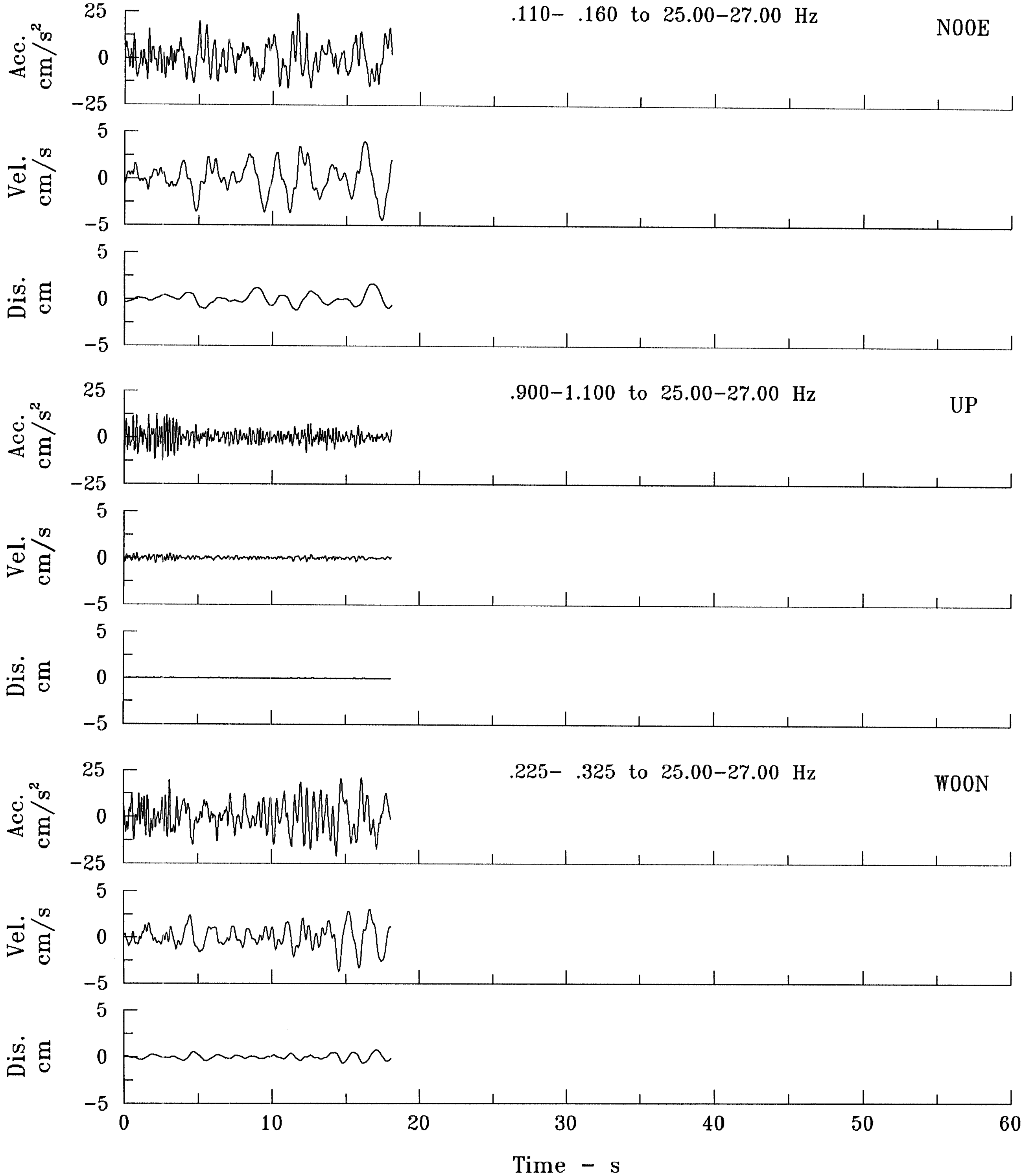


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -7) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

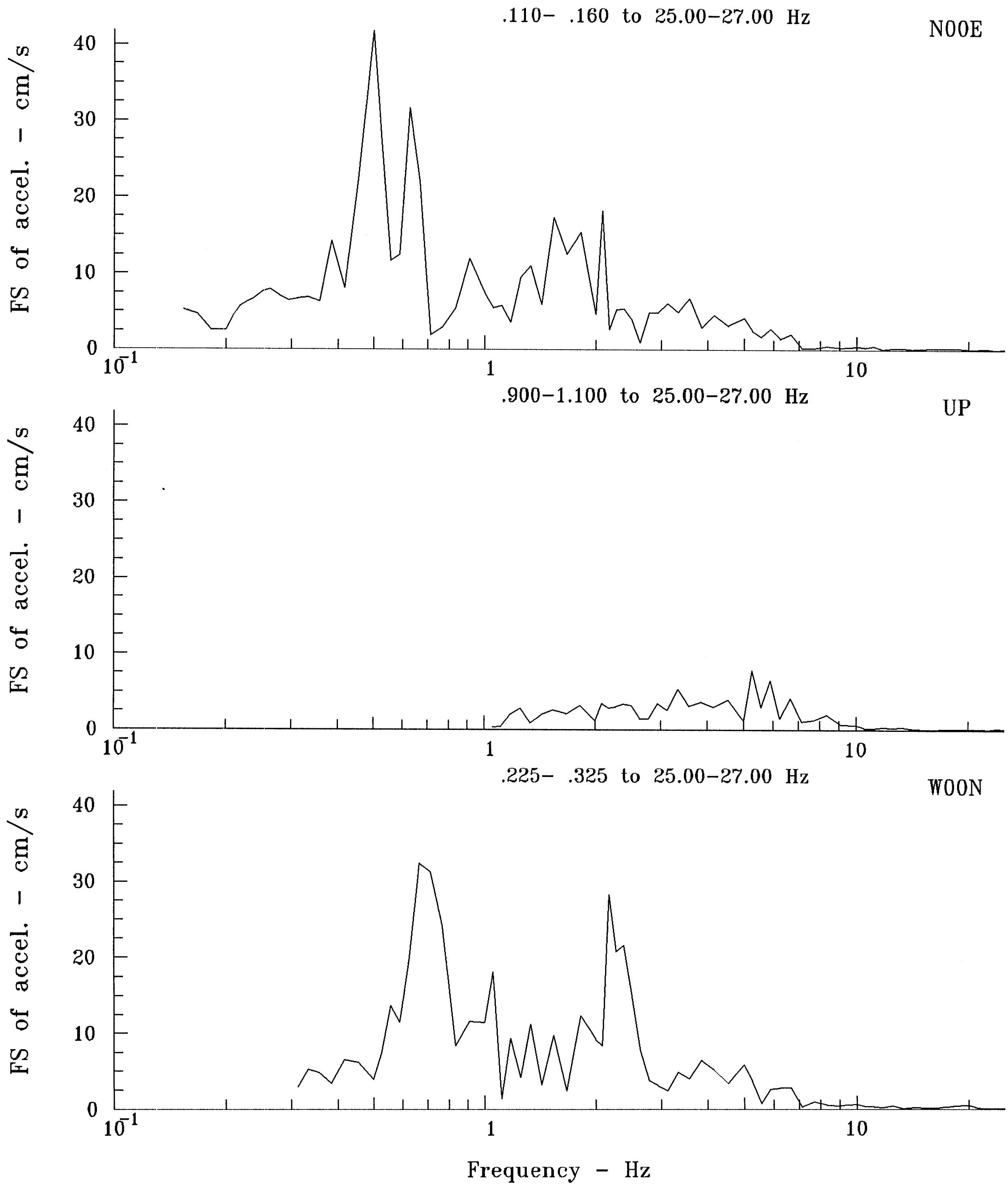


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -7) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

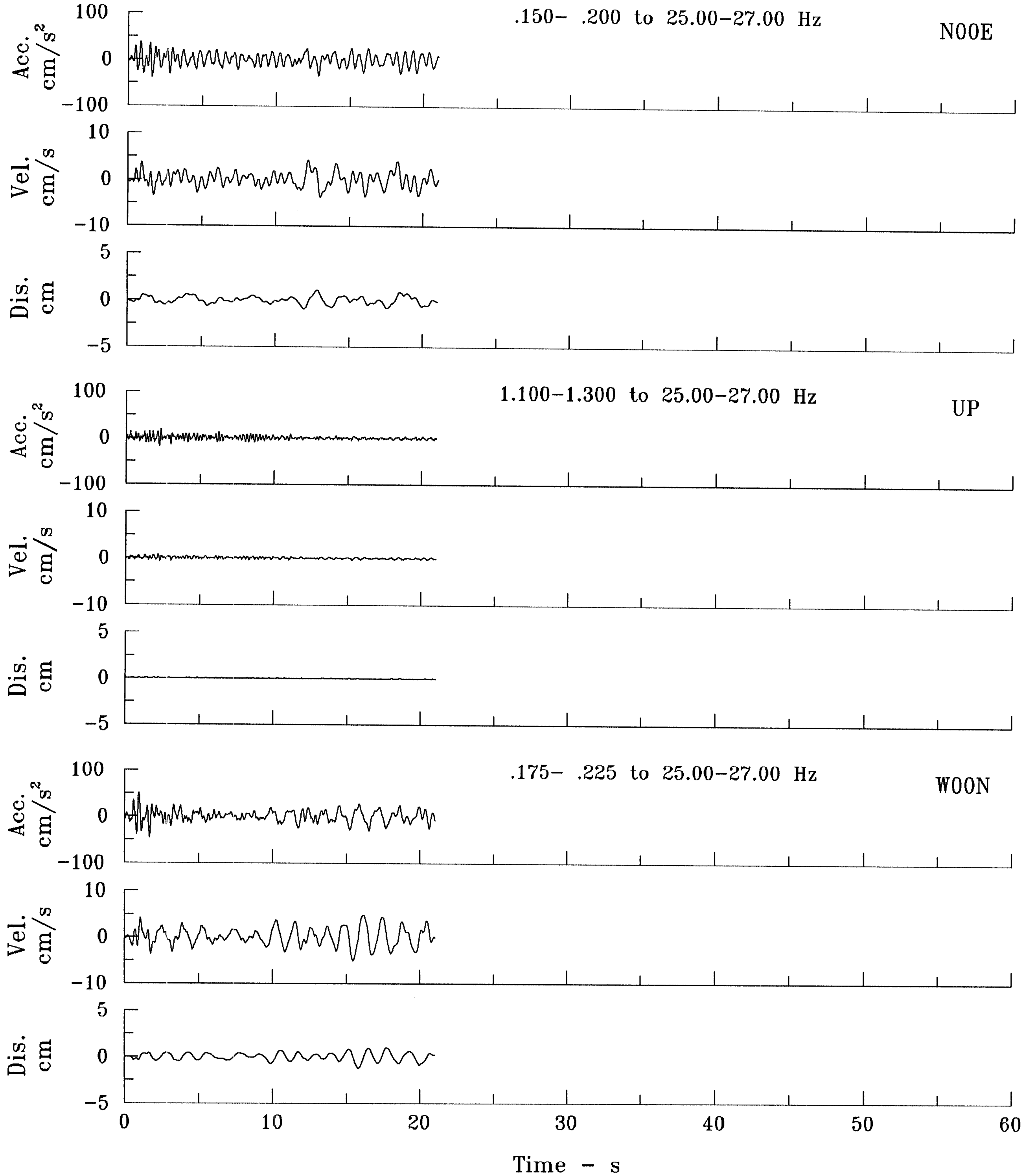


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -24) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

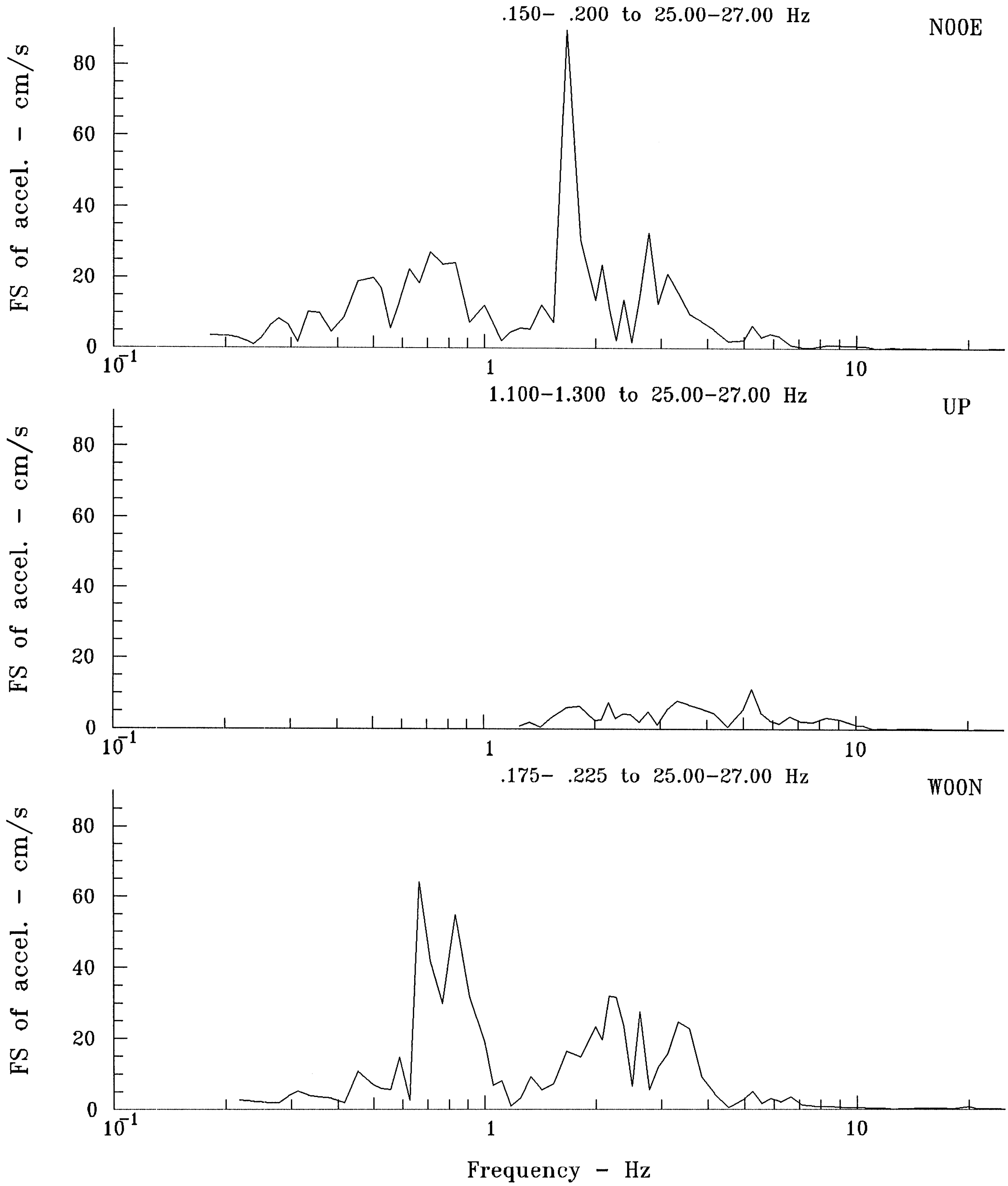


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -24) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

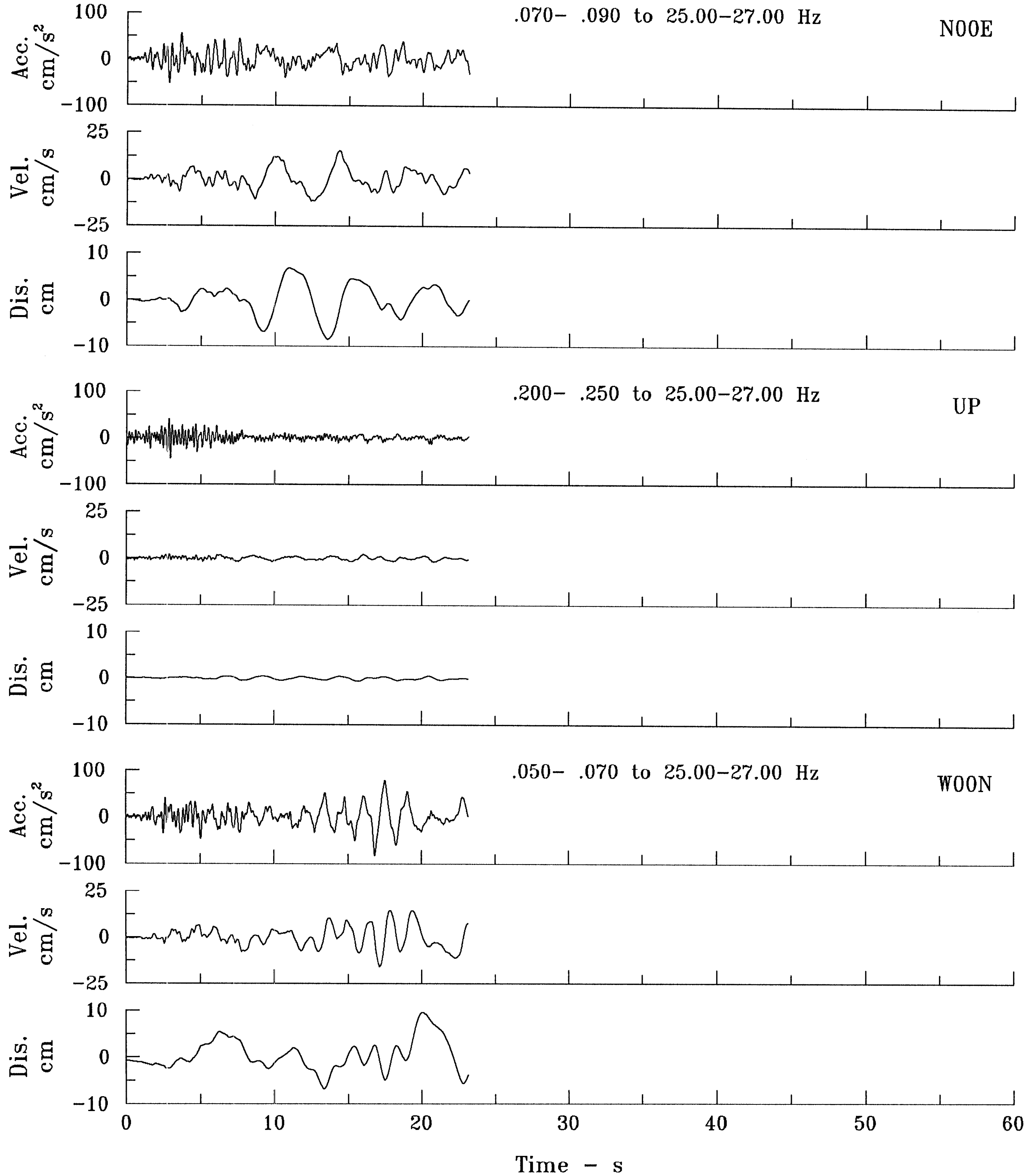


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -26) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

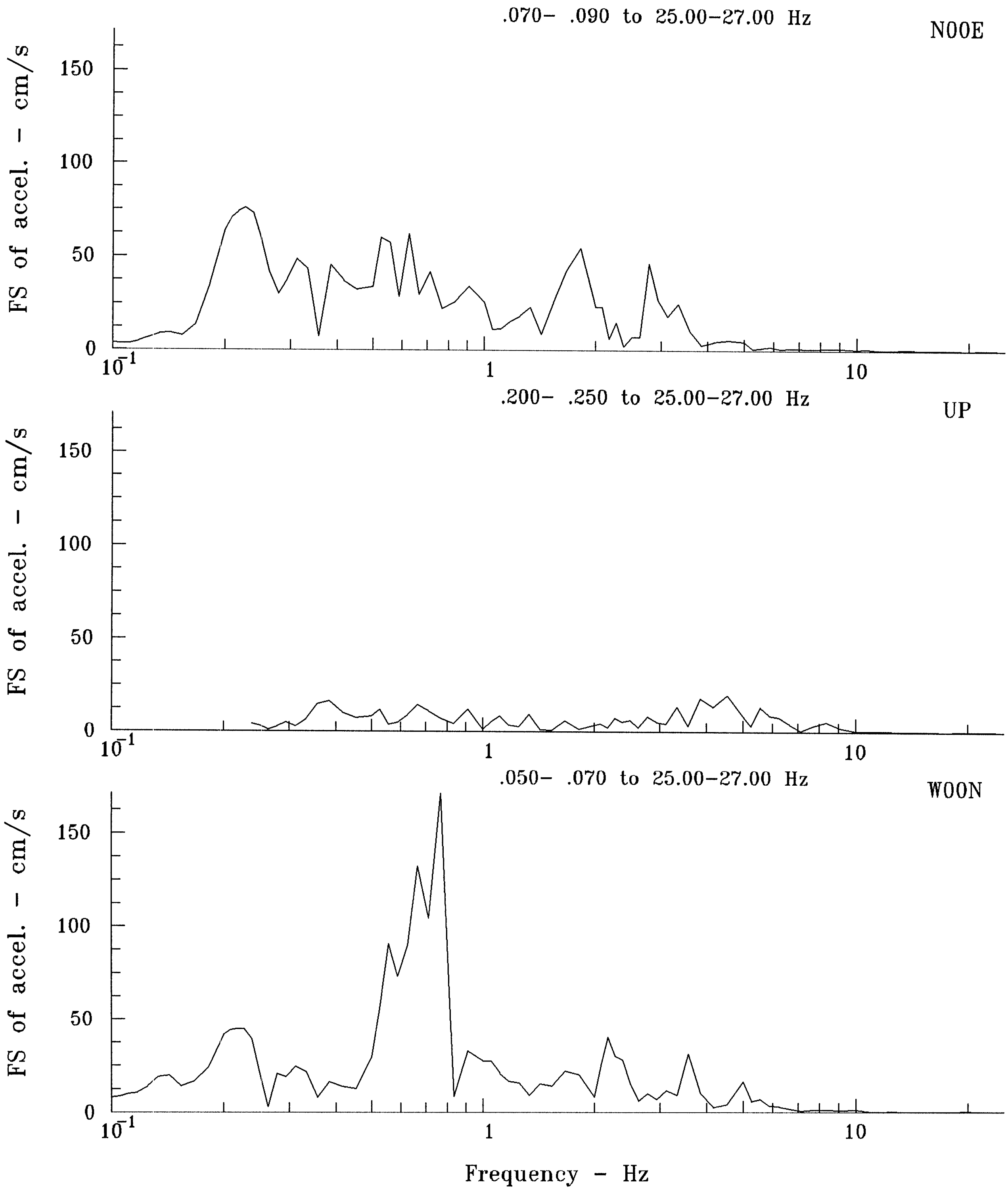


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -26) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

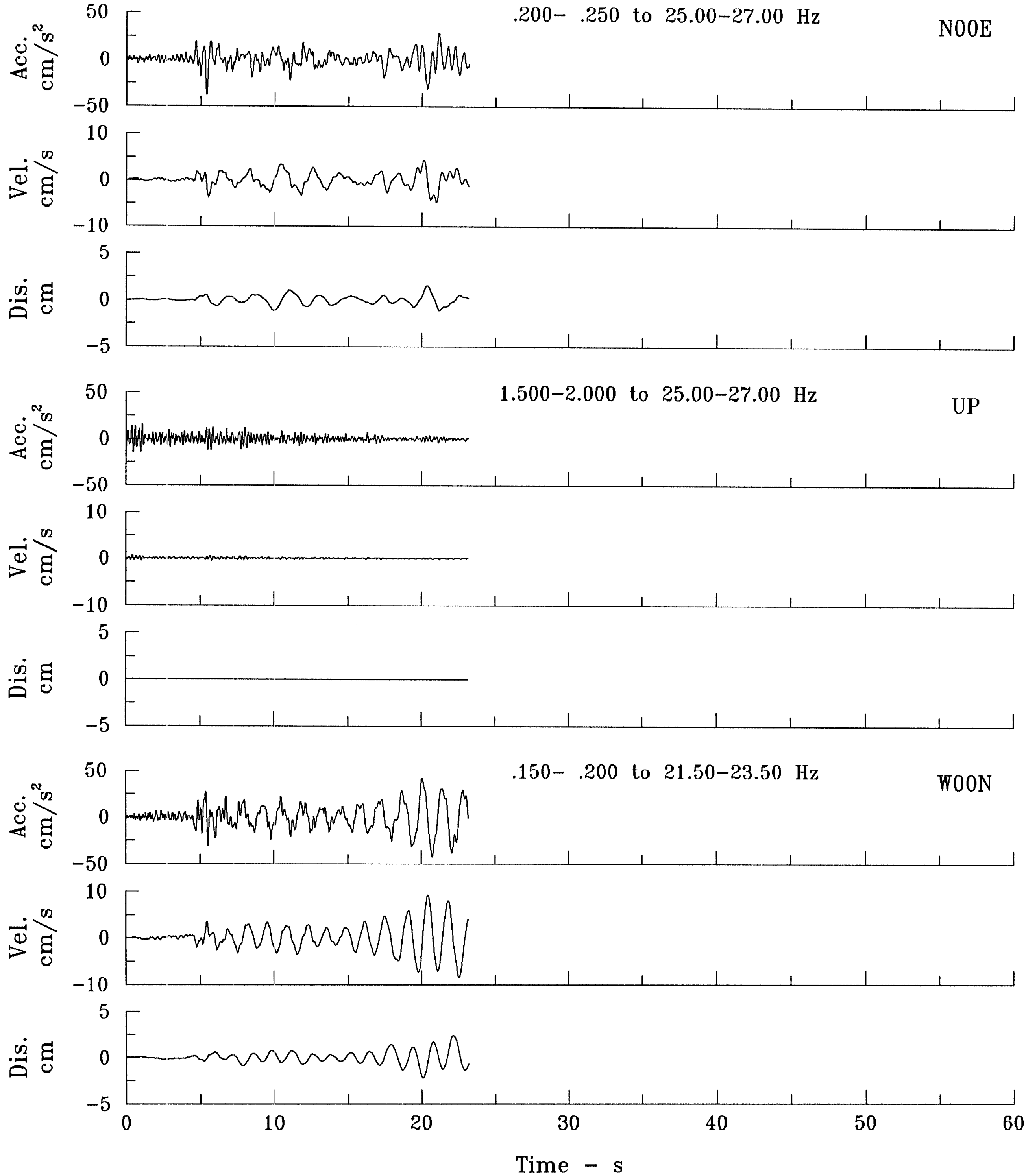


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -29) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

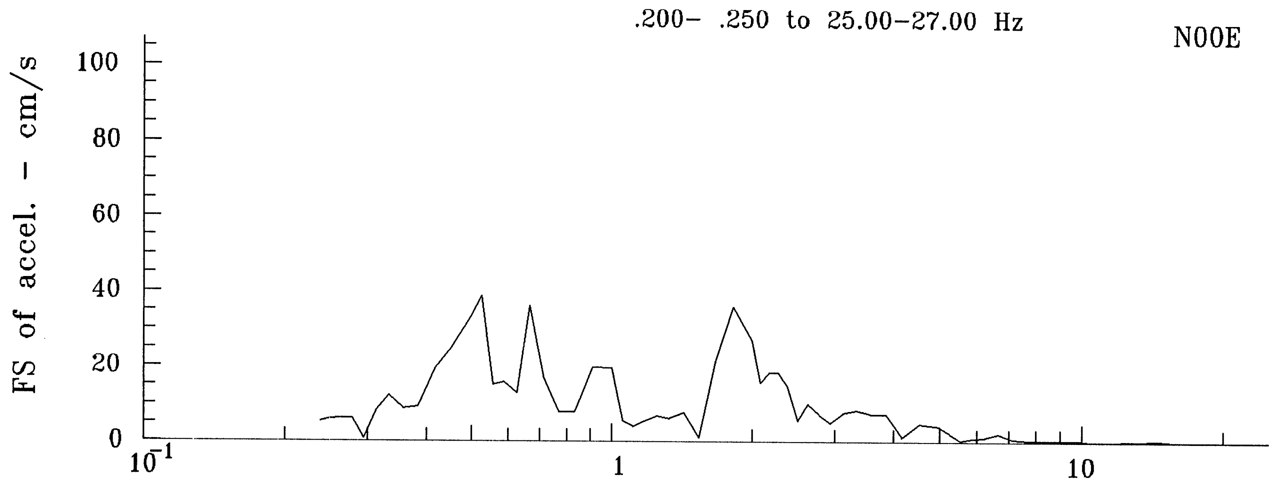


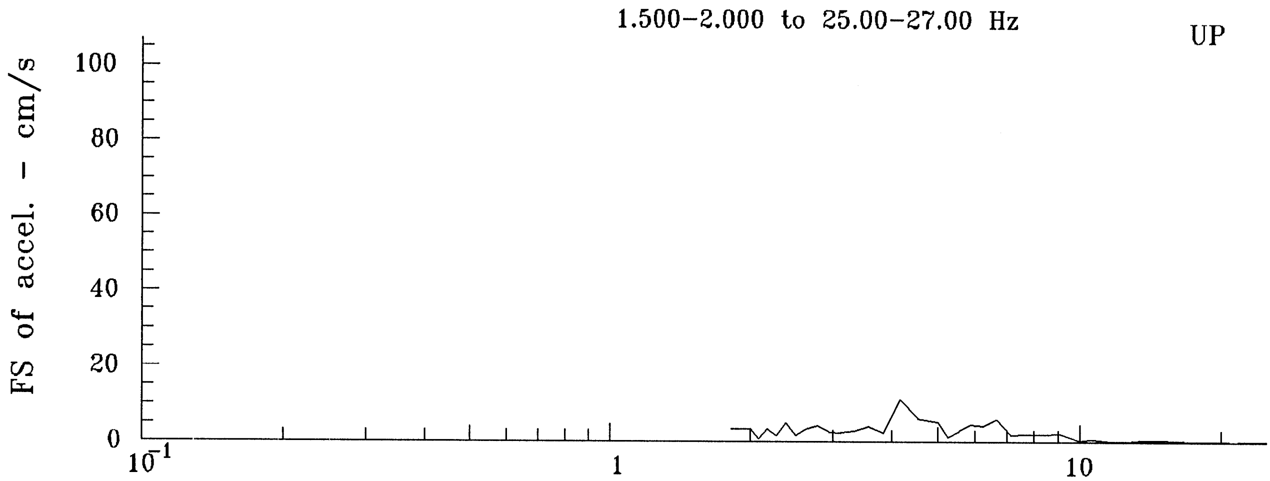
STATION USGS 5453 34.175 N, 118.465 W SMA 7073

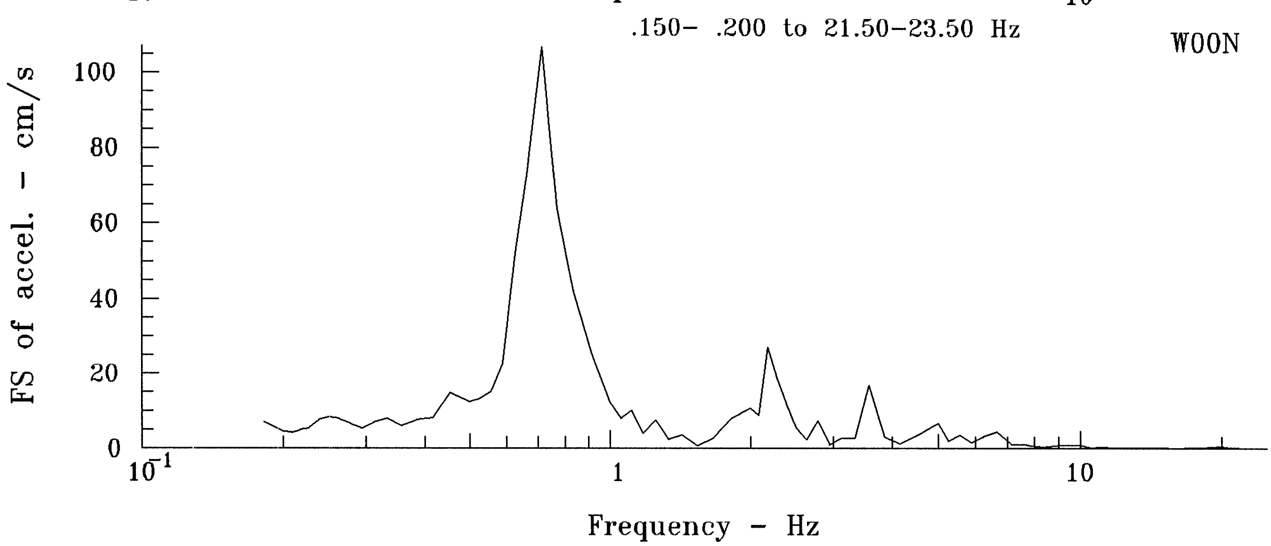
LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -29) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM





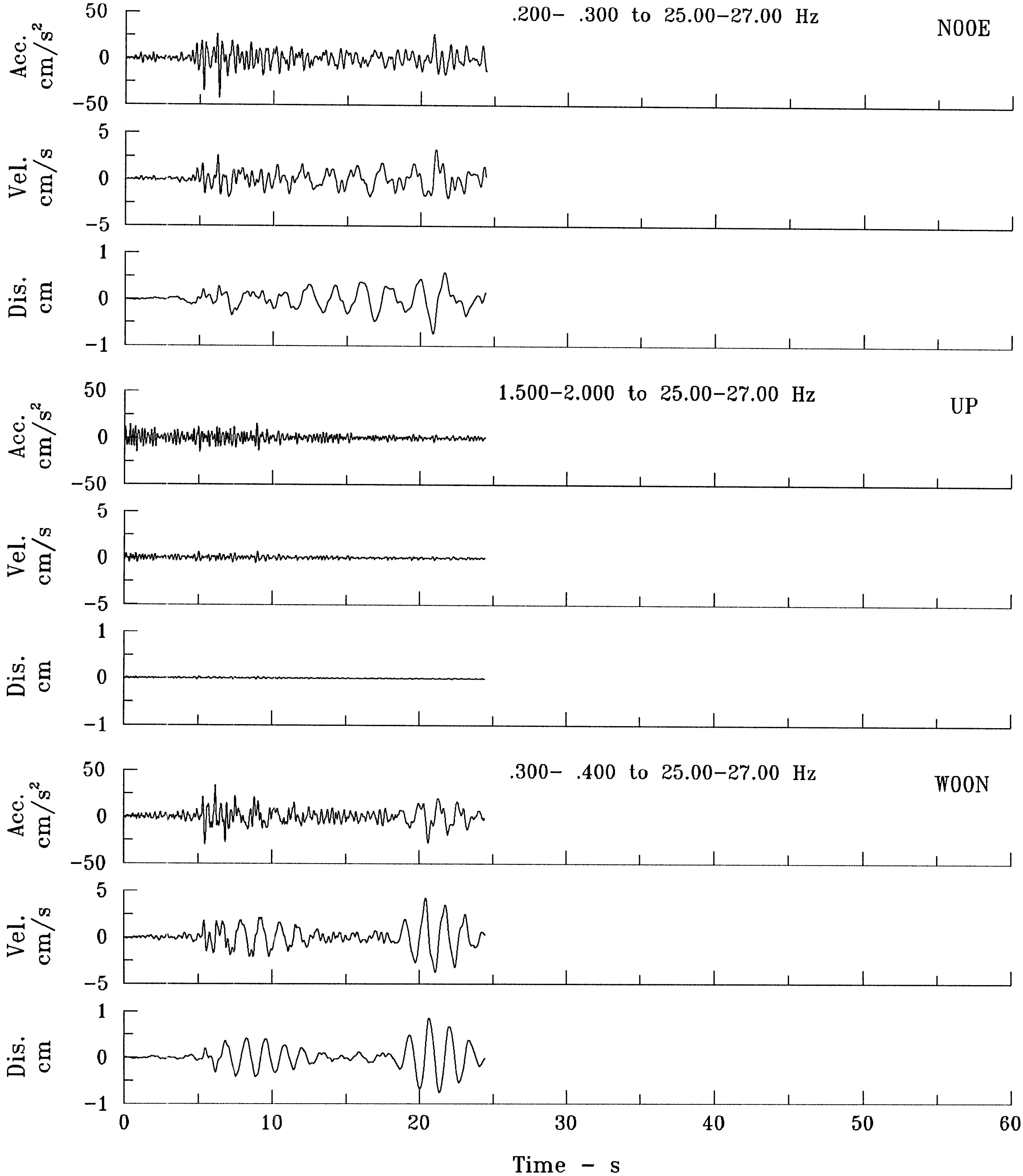


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -103) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

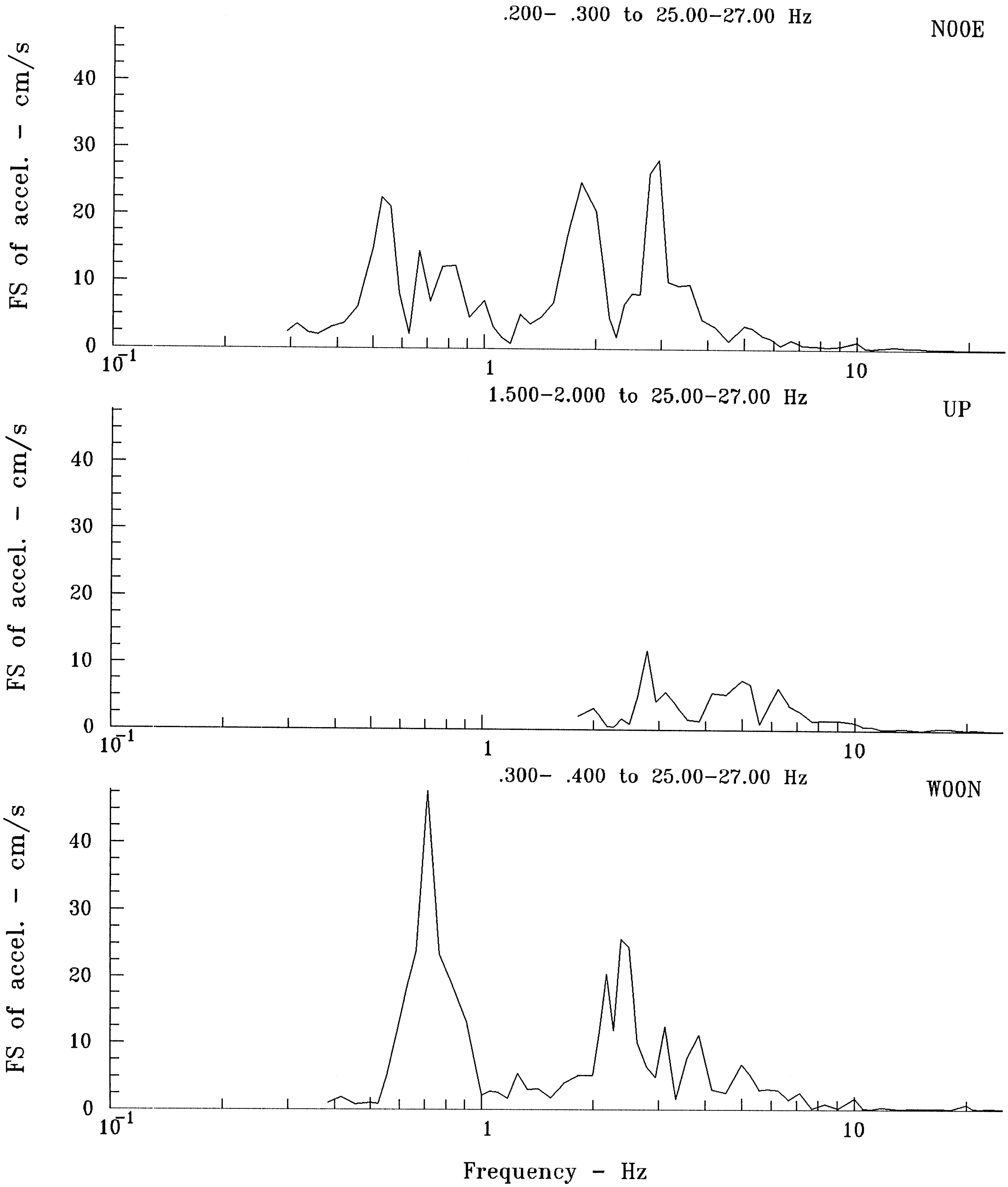


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -103) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

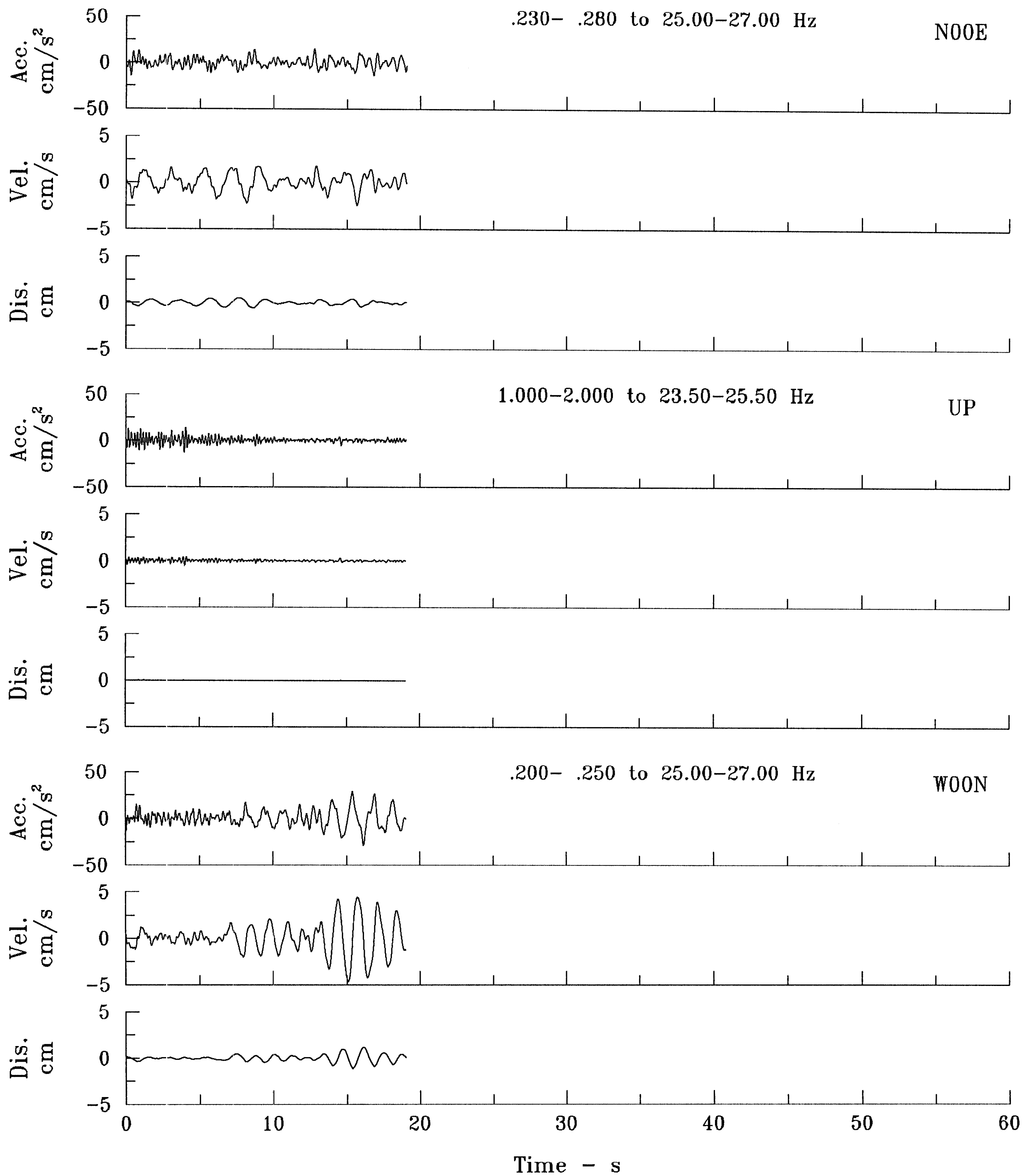


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -104) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

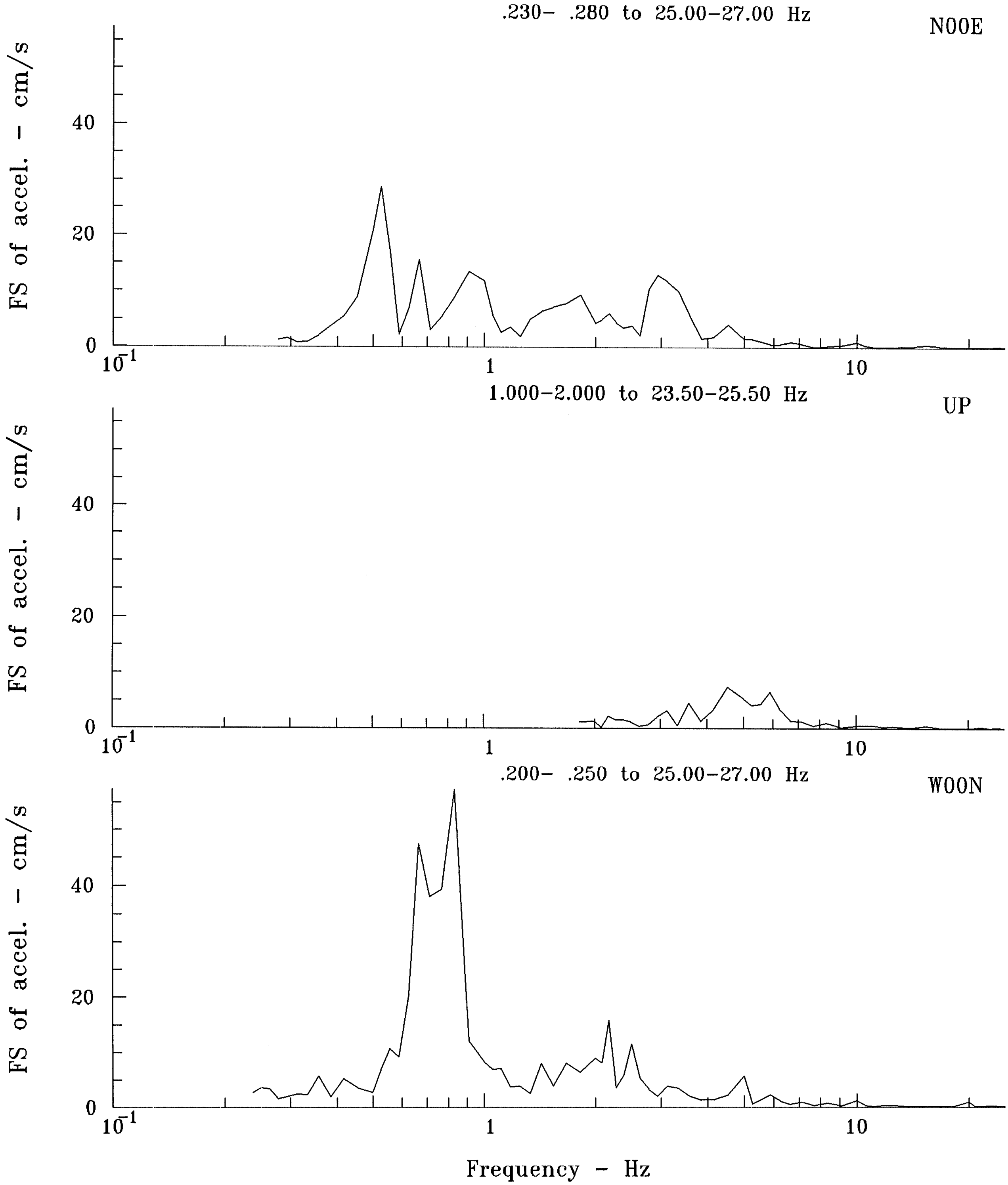


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -104) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

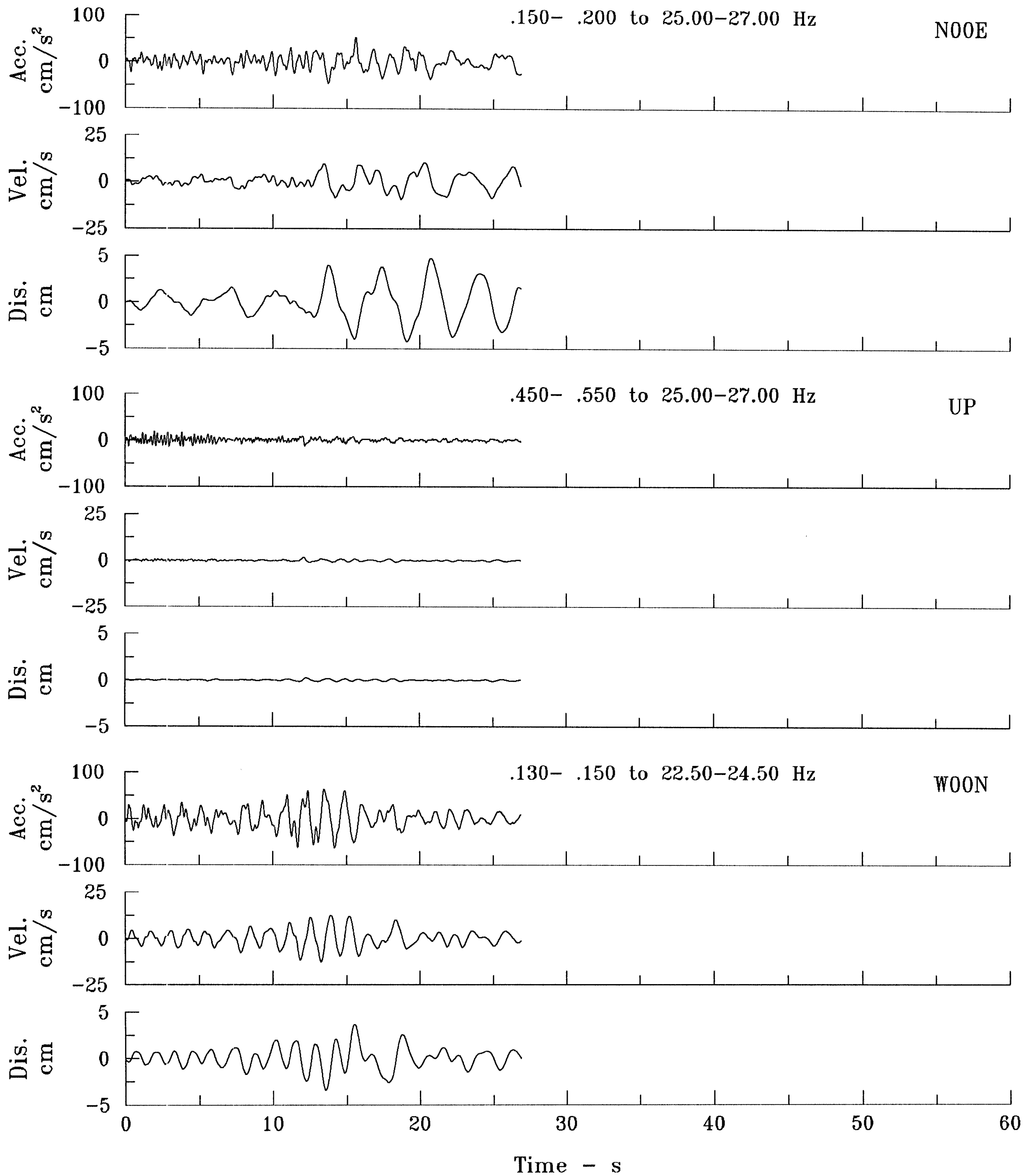


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -115) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM

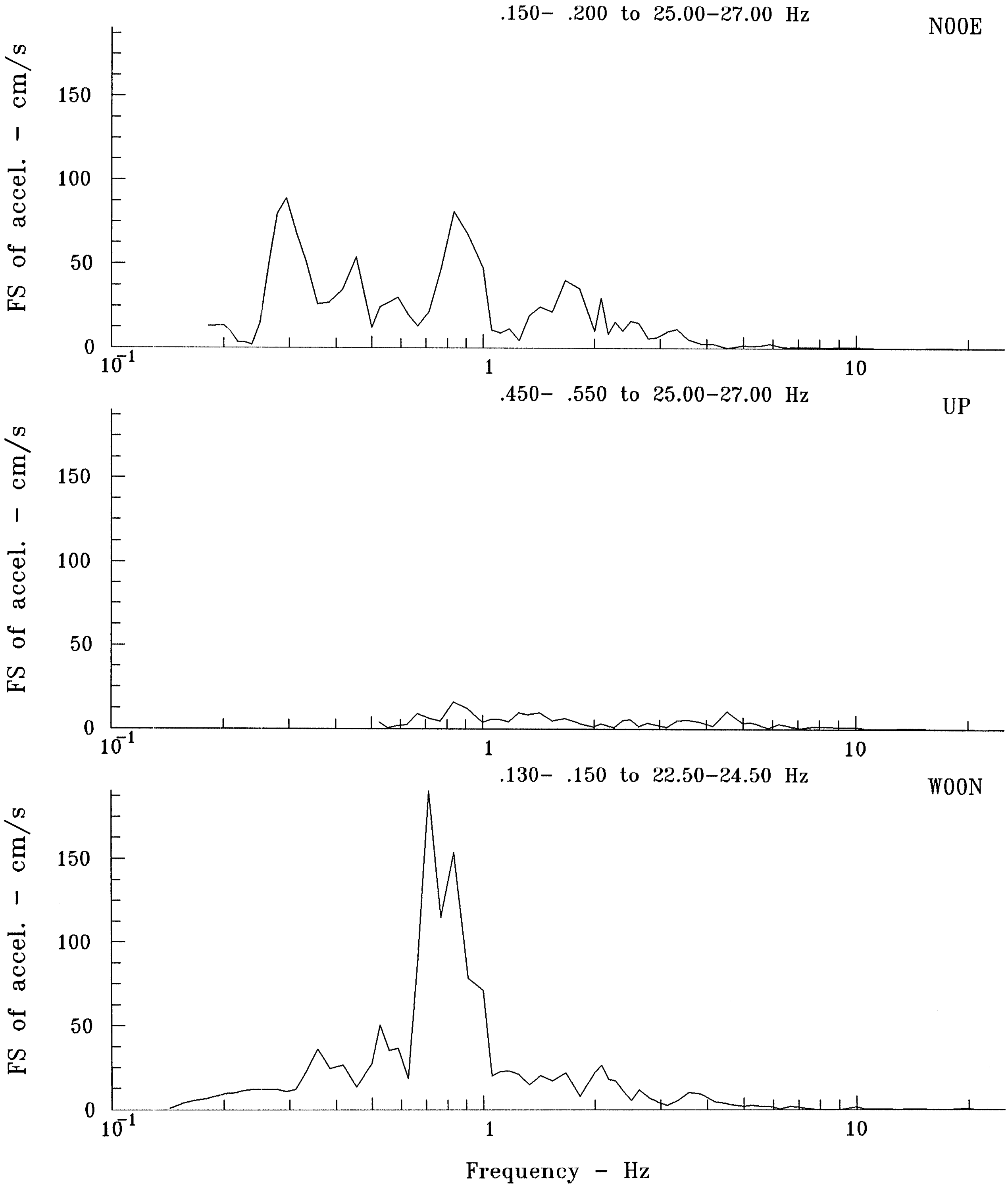


STATION USGS 5453 34.175 N, 118.465 W SMA 7073

LOS ANGELES, 5805 SEPULVEDA BLVD., ROOF (9th floor)

NORTHRIDGE EARTHQUAKE (aft. -115) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 13.98 KM



Appendix A.5455

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

Table A.5455.1 List of processed records

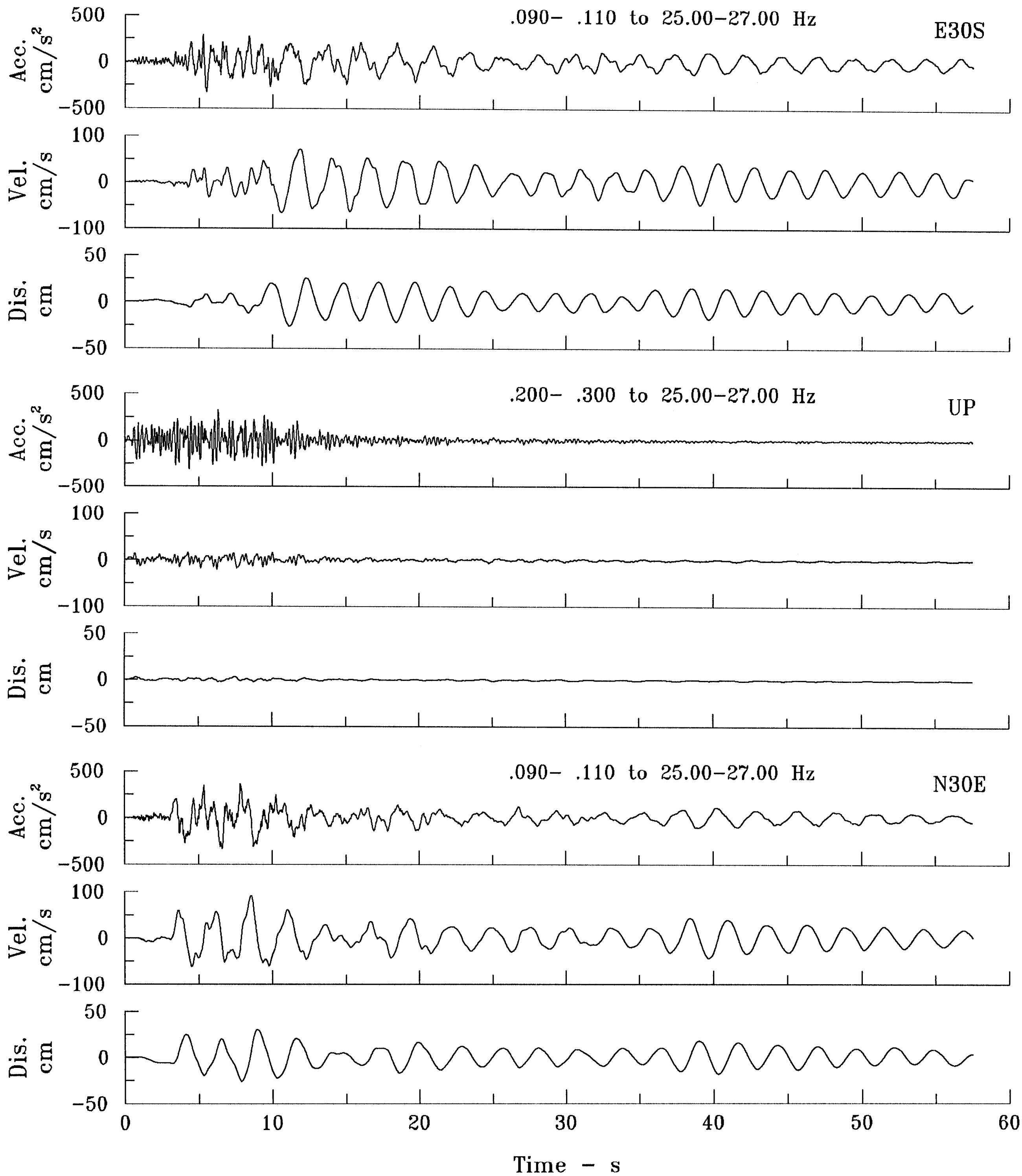
USGS: 5455 SMA-1 4270	LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)					34.156°N 118.480°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp.	Peak Acc. [g]
v1x0000.dat	IAA000	94.000.0	NORTHRIDGE EARTHQUAKE	8.2	57.6	E30S	0.358
						UP	0.337
						N30E	0.394
v1x0001.dat	IAA001	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	15.9	28.2	E30S	0.070
						UP	0.087
						N30E	0.104
v1x0007.dat	IAA007	94.000.7	NORTHRIDGE EARTHQUAKE (aft. -7)	15.9	23.1	E30S	0.018
						UP	0.033
						N30E	0.016
v1x0022.dat	IAA022	94.002.2	NORTHRIDGE EARTHQUAKE (aft. -22)	15.9	20.9	E30S	0.033
						UP	0.072
						N30E	0.029
v1x0025.dat	IAA025	94.002.5	NORTHRIDGE EARTHQUAKE (aft. -25)	15.9	34.7	E30S	0.043
						UP	0.056
						N30E	0.057
v1x0046.dat	IAA046	94.004.6	NORTHRIDGE EARTHQUAKE (aft. -46)	15.9	19.2	E30S	0.029
						UP	0.045
						N30E	0.041

STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 8.25 KM

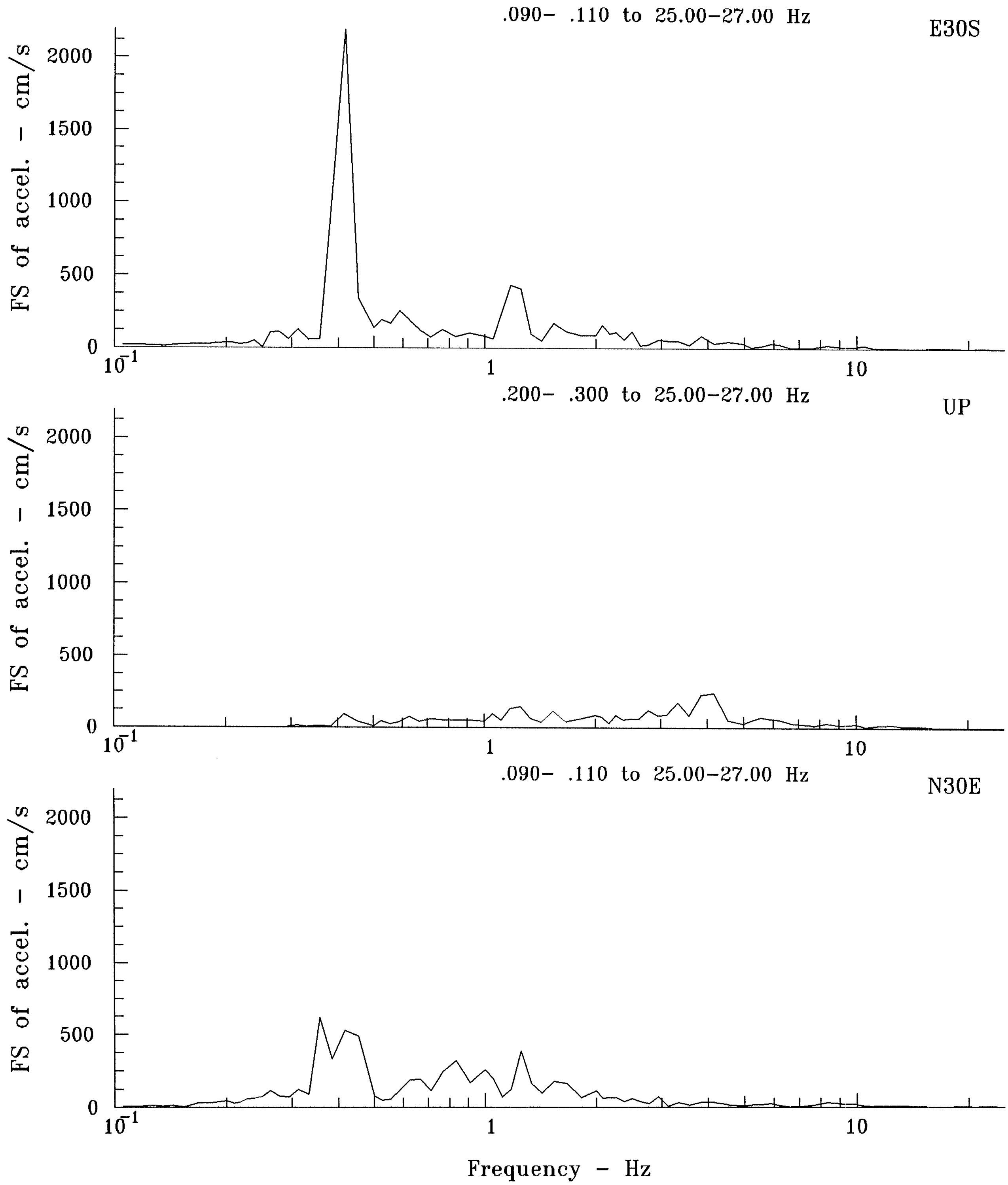


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 8.25 KM

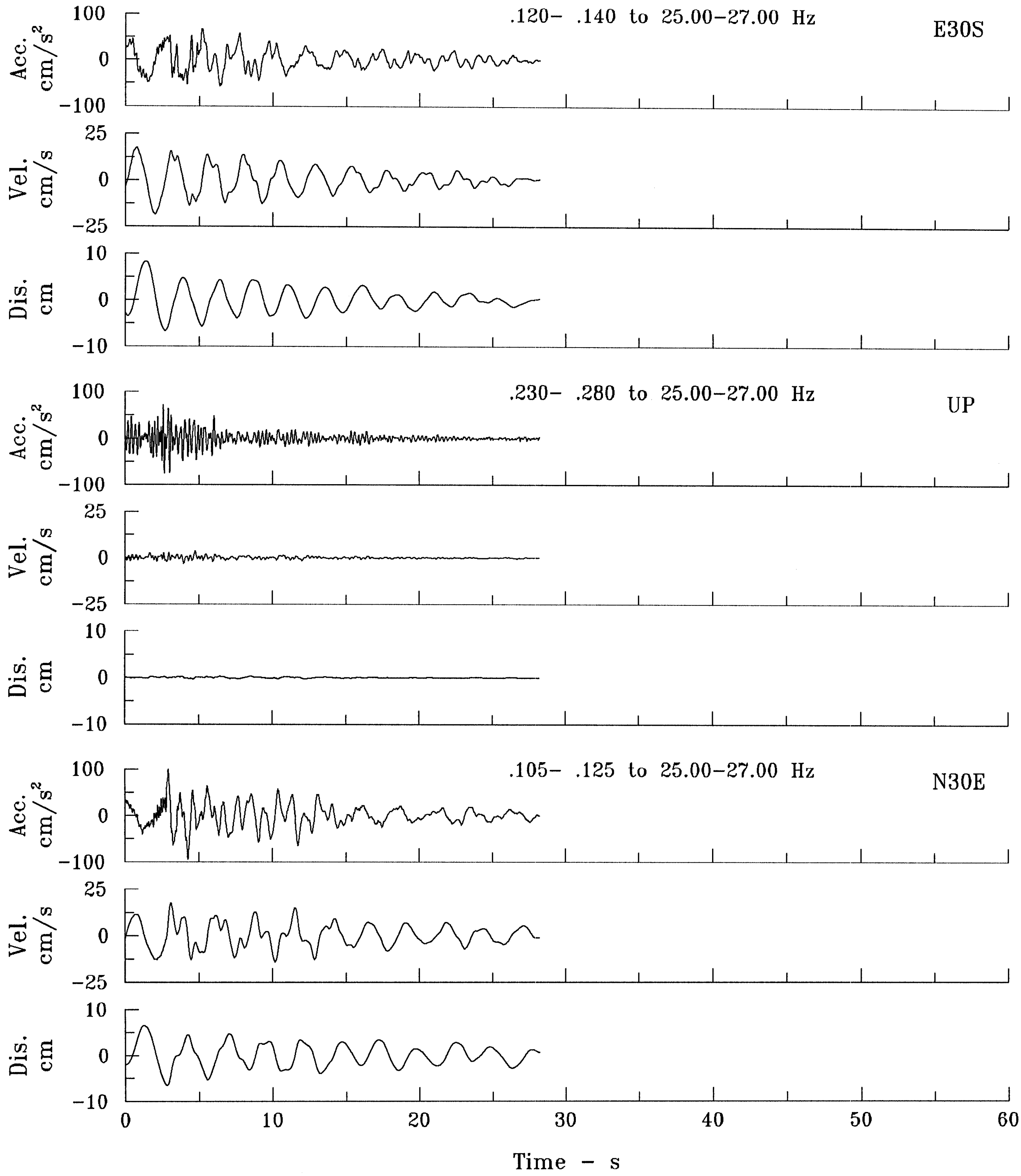


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM

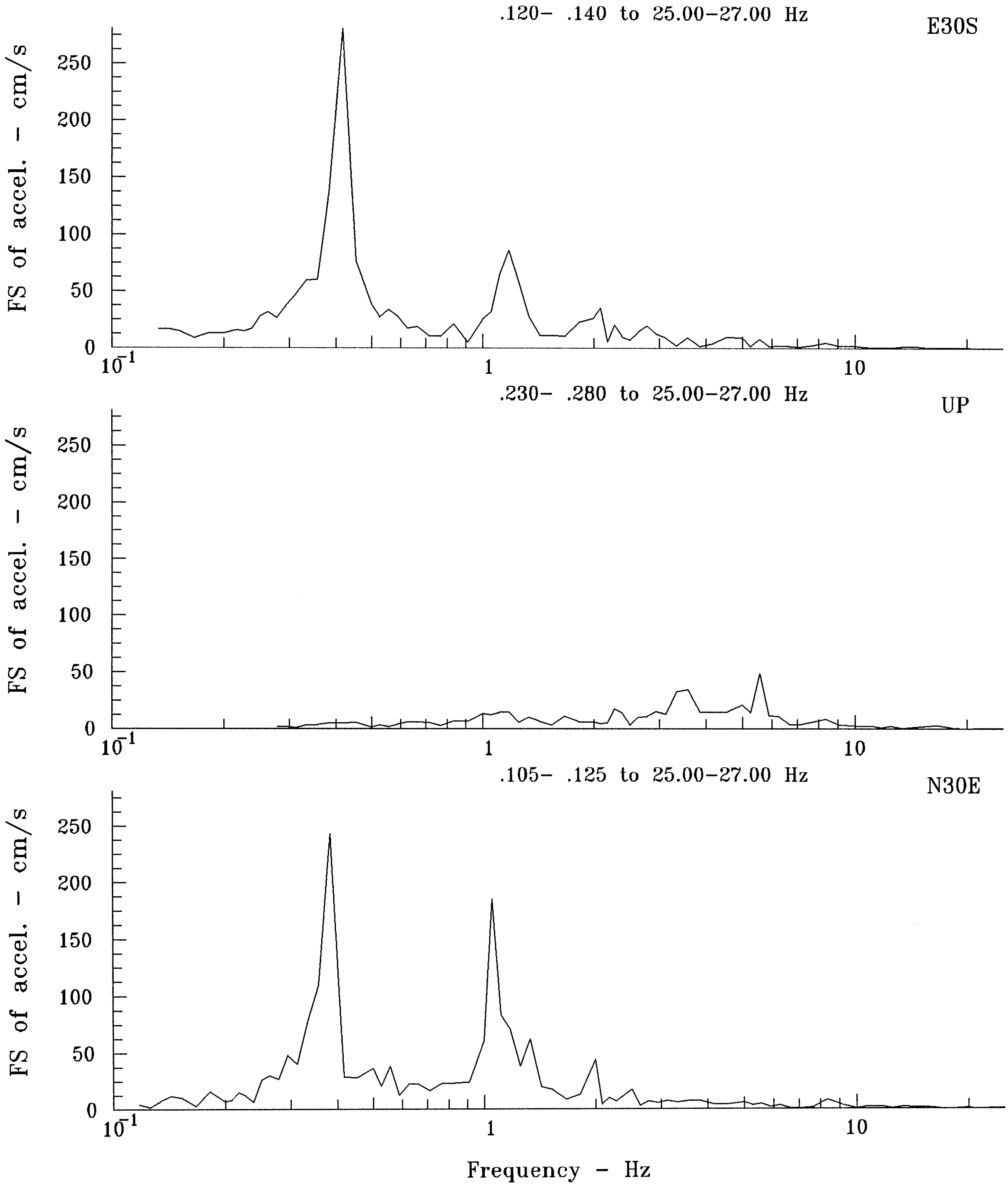


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -1) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM

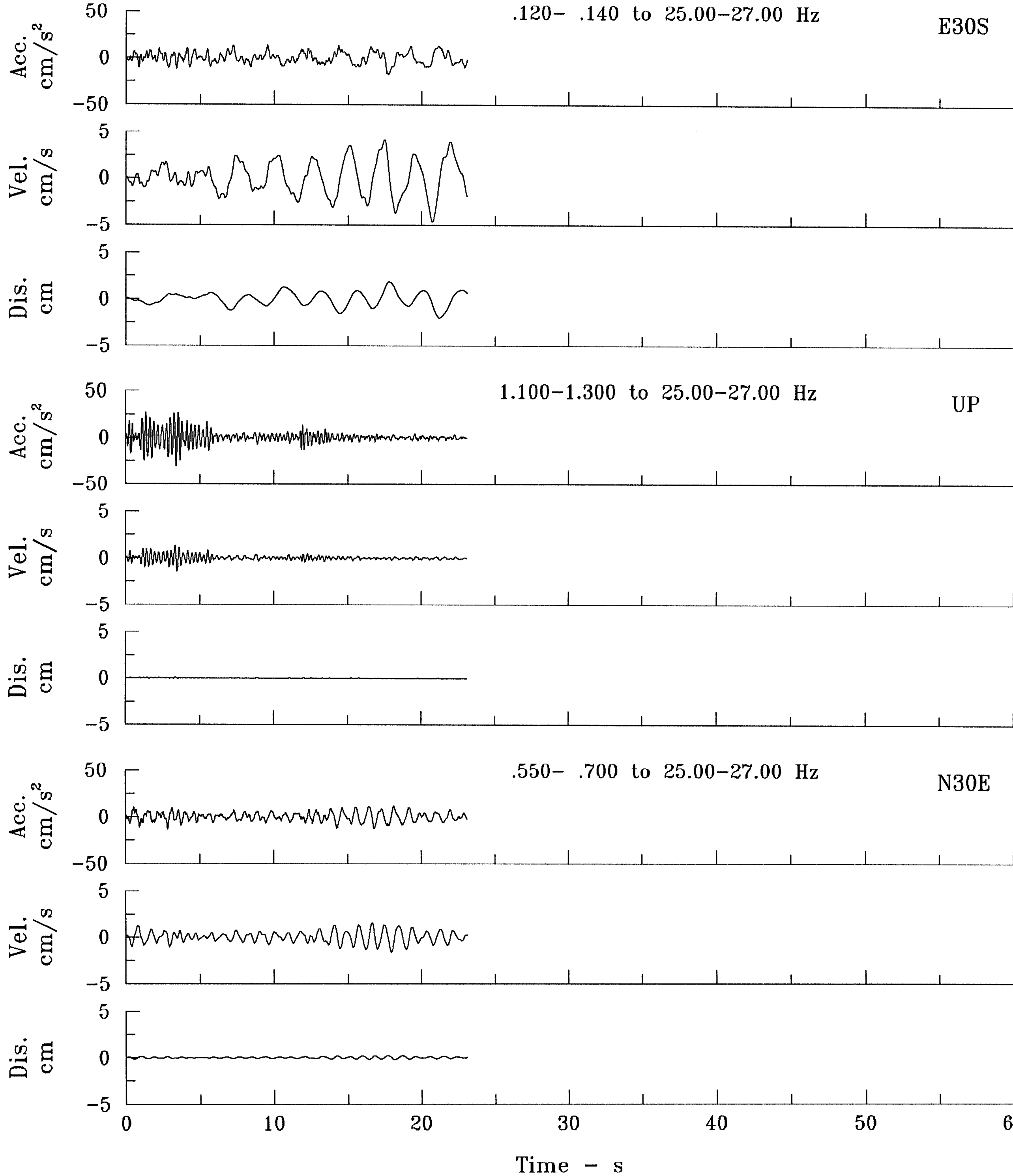


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -7) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM

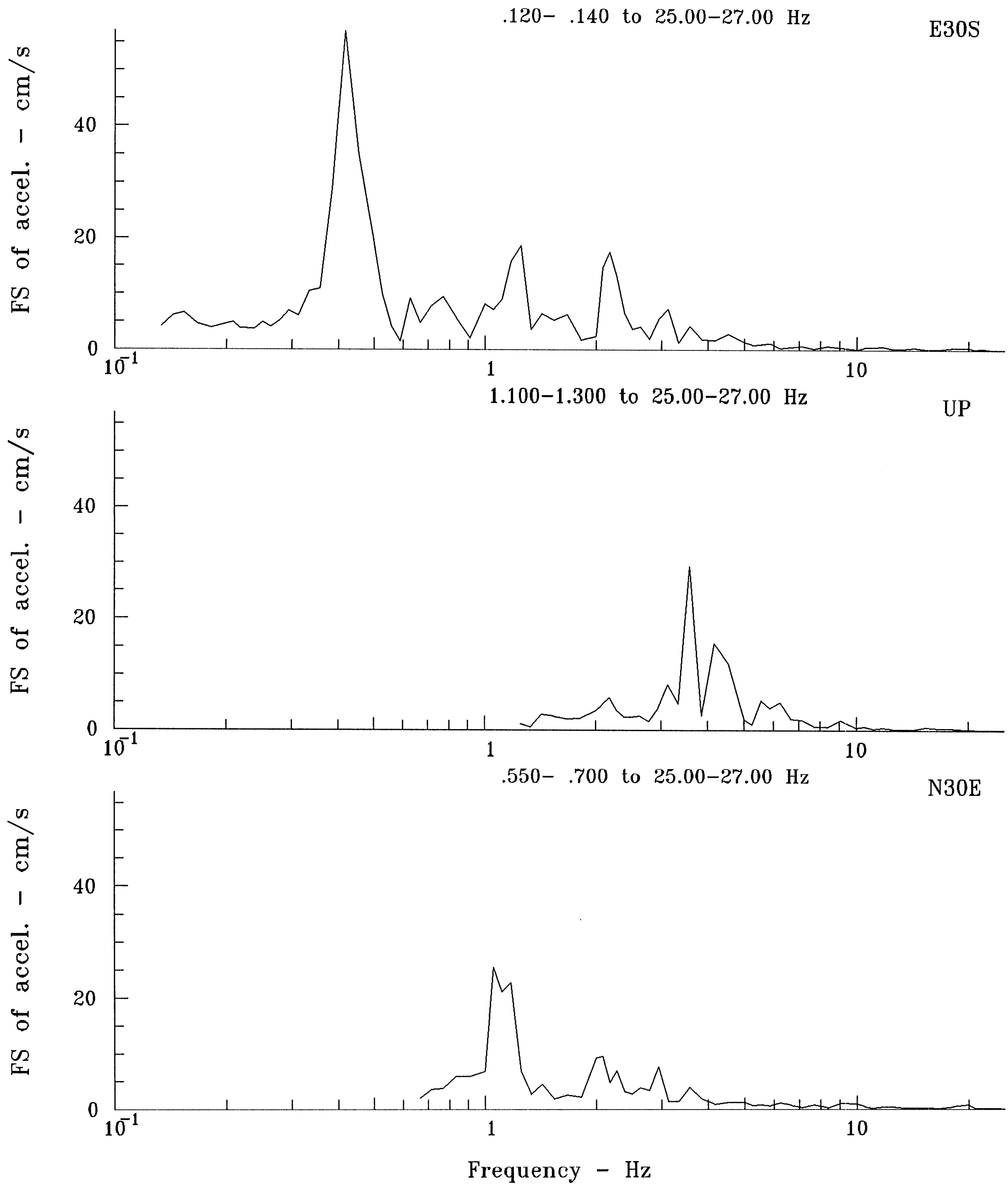


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -7) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM

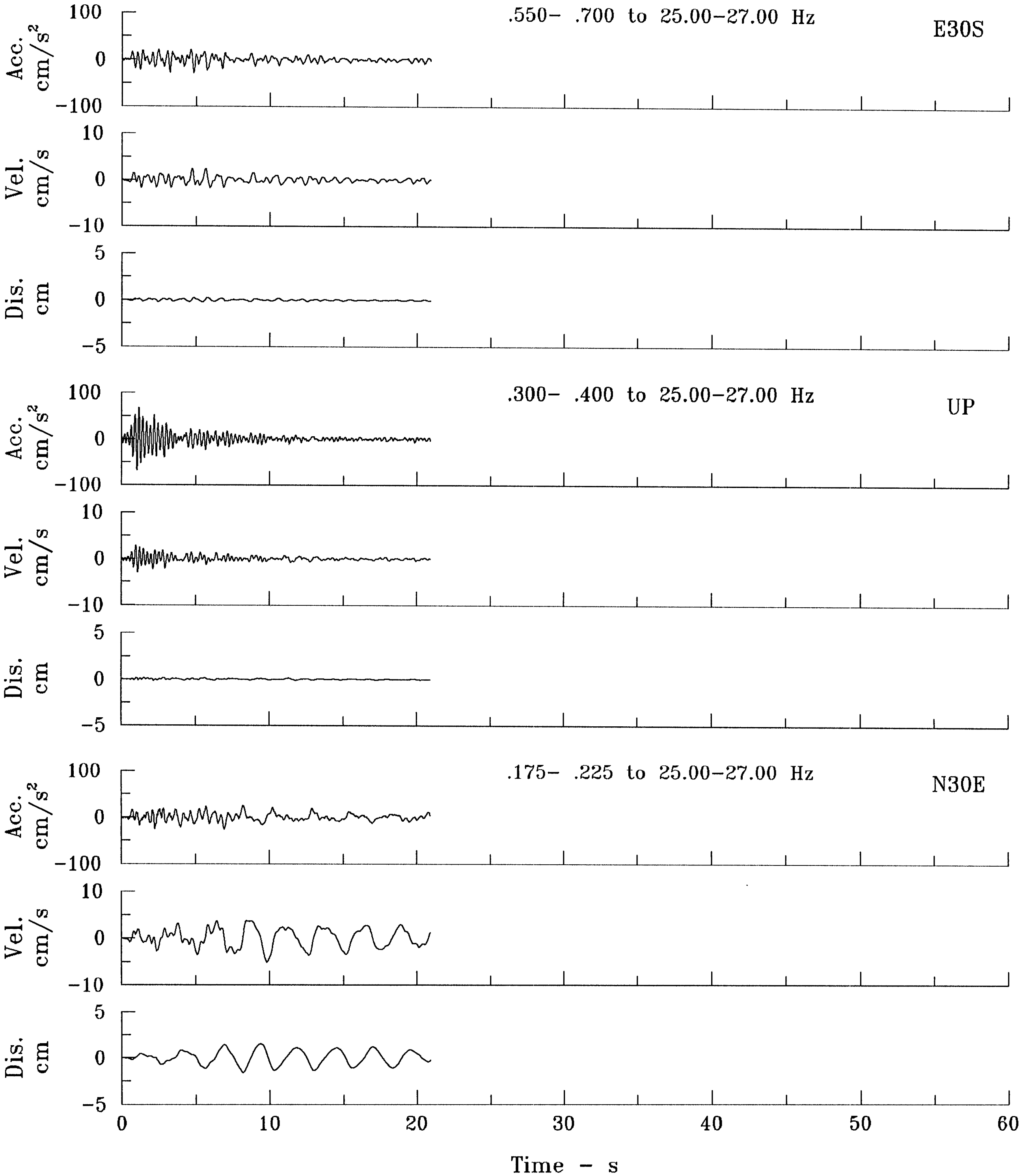


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -22) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM

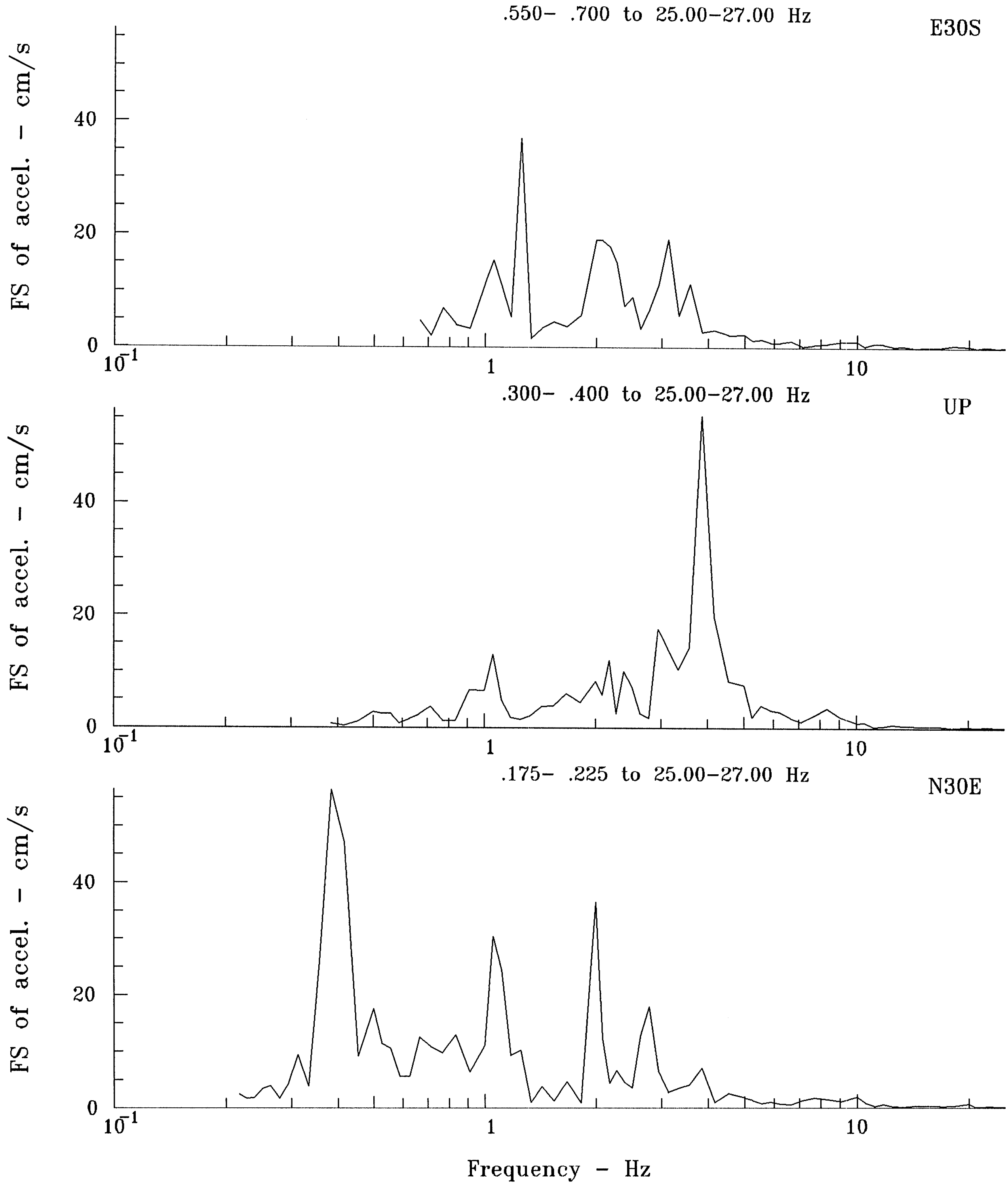


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -22) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM

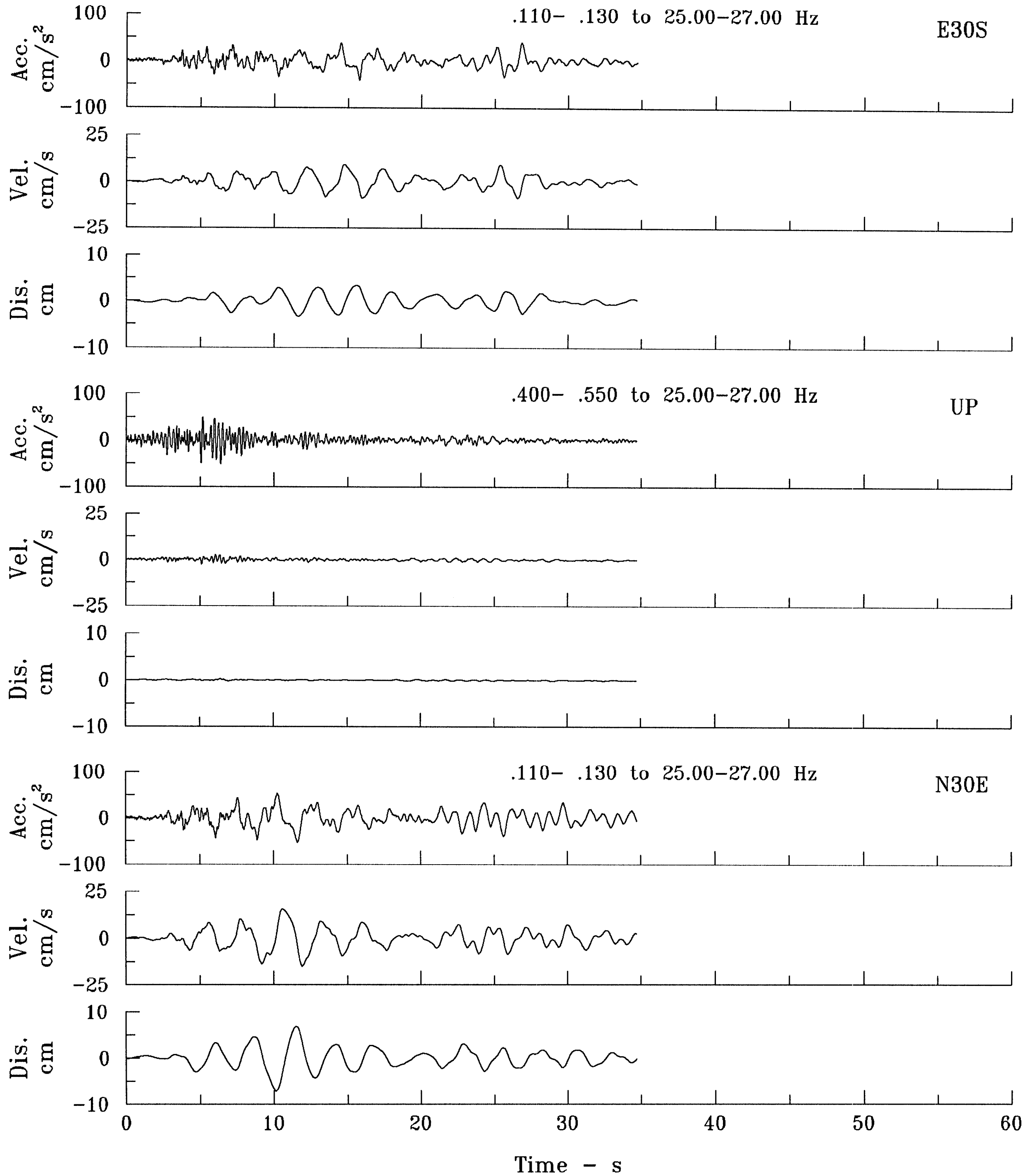


STATION USGS 5455   34.156 N, 118.480 W   SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -25)   ?????? 1994 -???? GMT

MAGNITUDE =   .0   EPICENTRAL DISTANCE = 15.94 KM

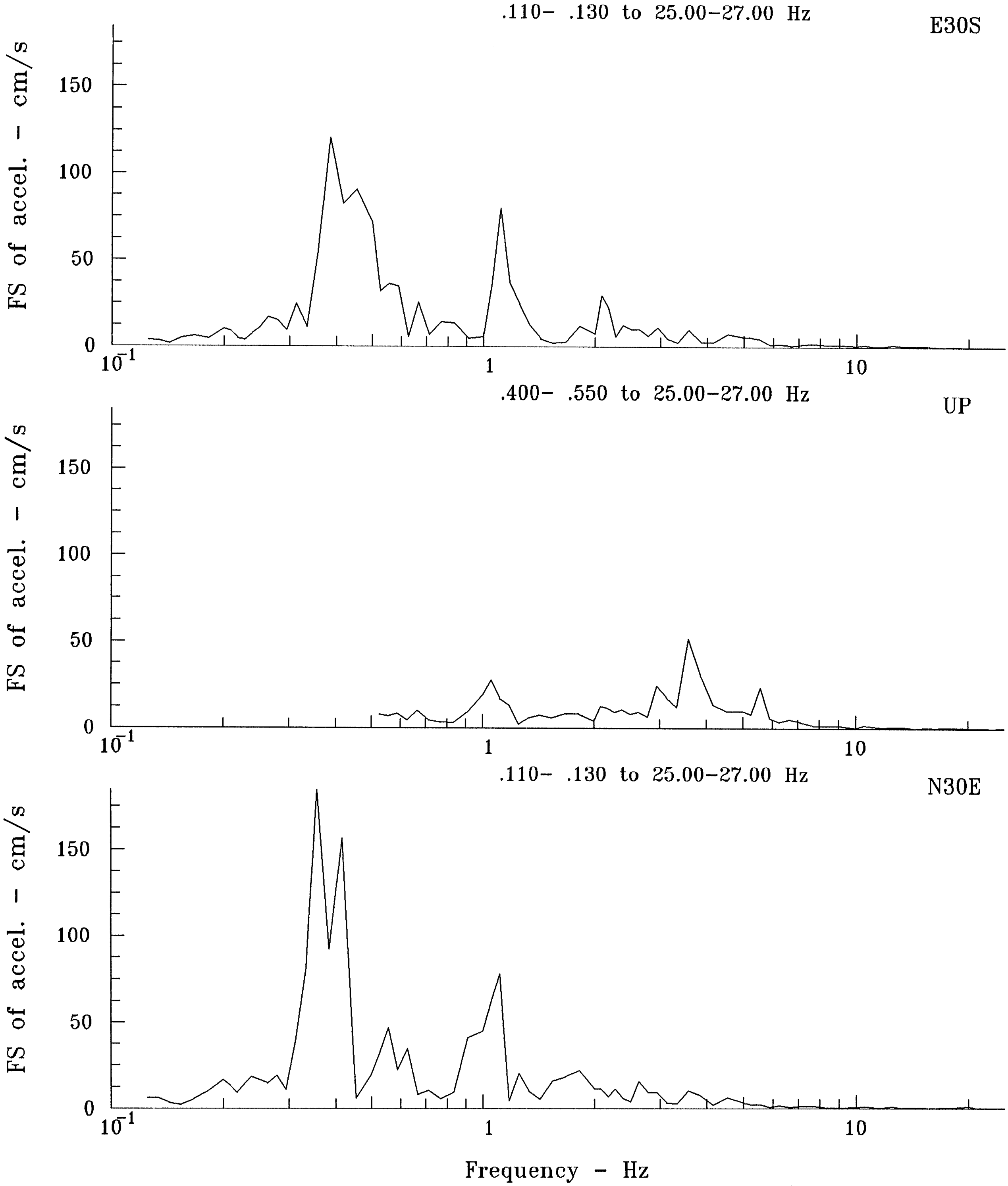


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -25) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM

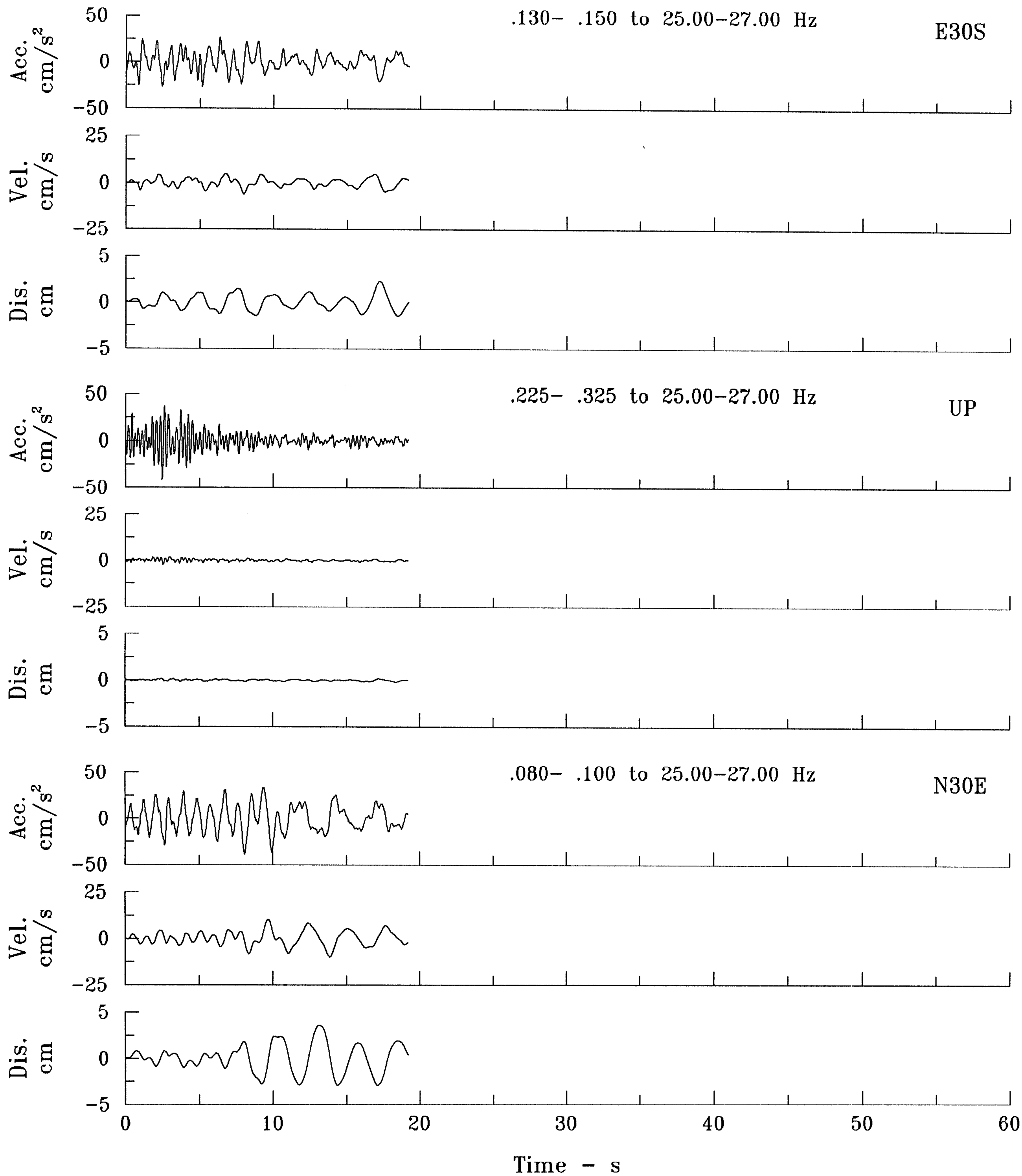


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -46) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM

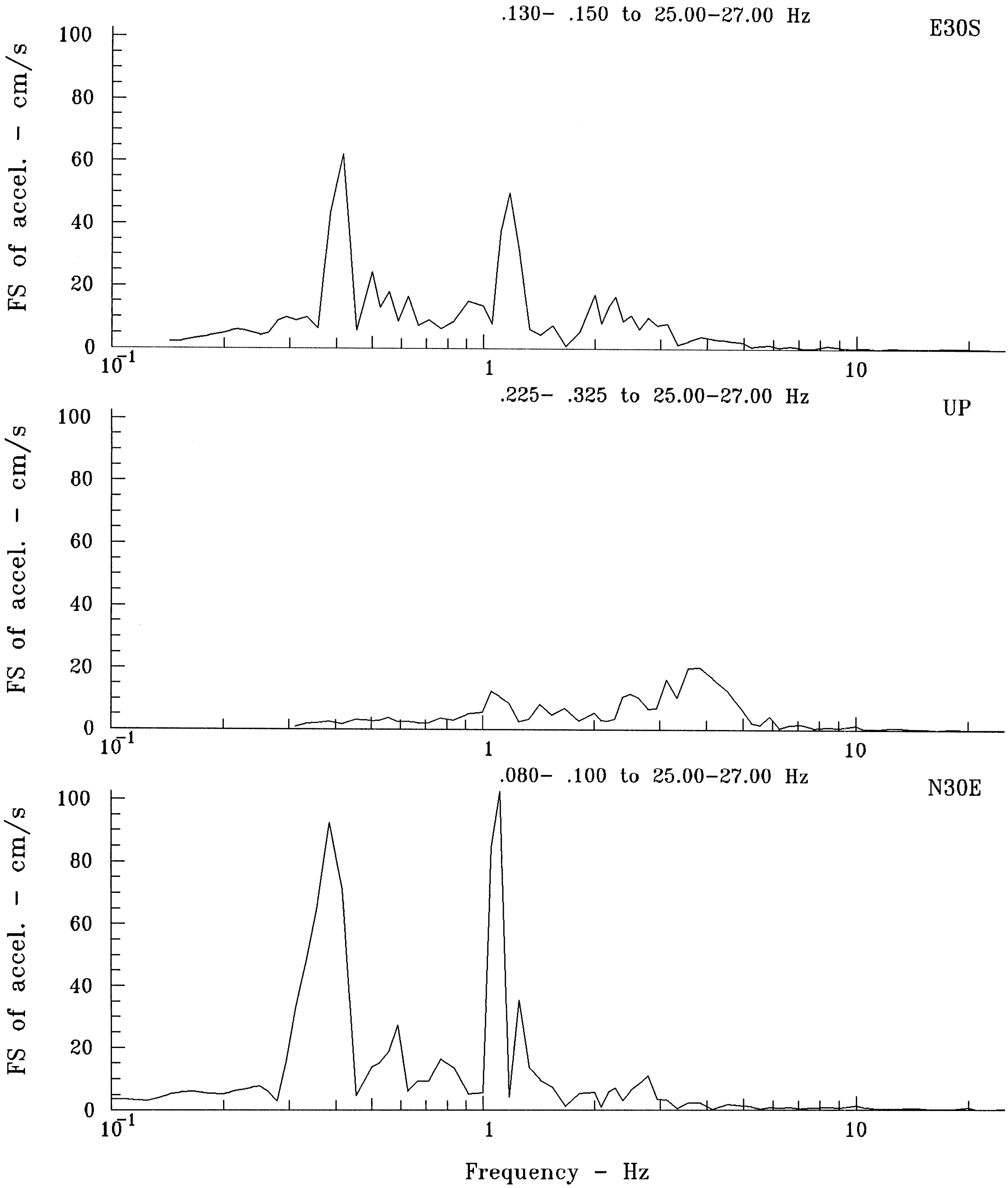


STATION USGS 5455 34.156 N, 118.480 W SMA-1 4270

LOS ANGELES, 16000 VENTURA BLVD., ROOF (13th floor)

NORTHRIDGE EARTHQUAKE (aft. -46) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 15.94 KM



Appendix A.5457

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th floor)

Table A.5457.1 List of processed records

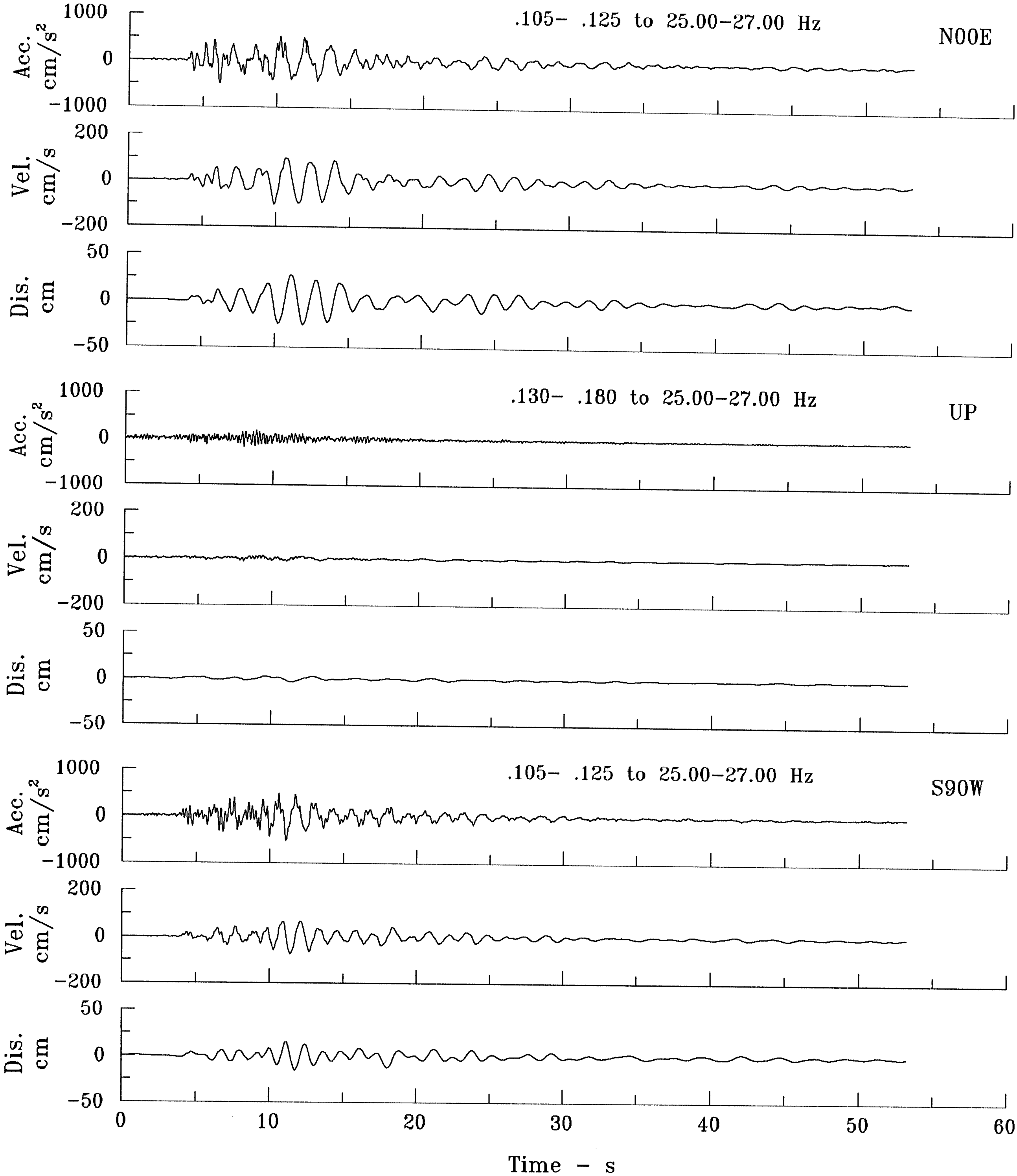
USGS: 5457 SMA 5491	LOS ANGELES, 8436 WEST 3rd ST., Roof (10th floor)					34.072°N 118.375°W	
File Name	Ref No.	Log No.	Earthquake	Distance [km]	Duration [s]	Comp.	Peak Acc. [g]
v1x0000.dat	IAA030	94.000.0	NORTHRIDGE EARTHQUAKE	21.7	53.2	N00E	0.658
						UP	0.253
						S90W	0.547
v1x0001.dat	IAA030	94.000.1	NORTHRIDGE EARTHQUAKE (aft. -1)	27.4	28.1	N00E	0.102
						UP	0.093
						S90W	0.262
v1x0004.dat	IAA030	94.000.4	NORTHRIDGE EARTHQUAKE (aft. -4)	27.4	20.3	N00E	0.014
						UP	0.022
						S90W	0.017
v1x0008.dat	IAA030	94.000.8	NORTHRIDGE EARTHQUAKE (aft. -8)	27.4	22.5	N00E	0.031
						UP	0.023
						S90W	0.057
v1x0009.dat	IAA030	94.000.9	NORTHRIDGE EARTHQUAKE (aft. -9)	27.4	27.5	N00E	0.053
						UP	0.032
						S90W	0.053
v1x0010.dat	IAA030	94.001.0	NORTHRIDGE EARTHQUAKE (aft. -10)	27.4	18.7	N00E	0.018
						UP	0.015
						S90W	0.014
v1x0013.dat	IAA030	94.001.3	NORTHRIDGE EARTHQUAKE (aft. -13)	27.4	21.6	N00E	0.027
						UP	0.014
						S90W	0.032
v1x0017.dat	IAA030	94.001.7	NORTHRIDGE EARTHQUAKE (aft. -17)	27.4	20.5	N00E	0.018
						UP	0.014
						S90W	0.021
v1x0019.dat	IAA030	94.001.9	NORTHRIDGE EARTHQUAKE (aft. -19)	27.4	30.9	N00E	0.100
						UP	0.124
						S90W	0.185

STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 21.72 KM

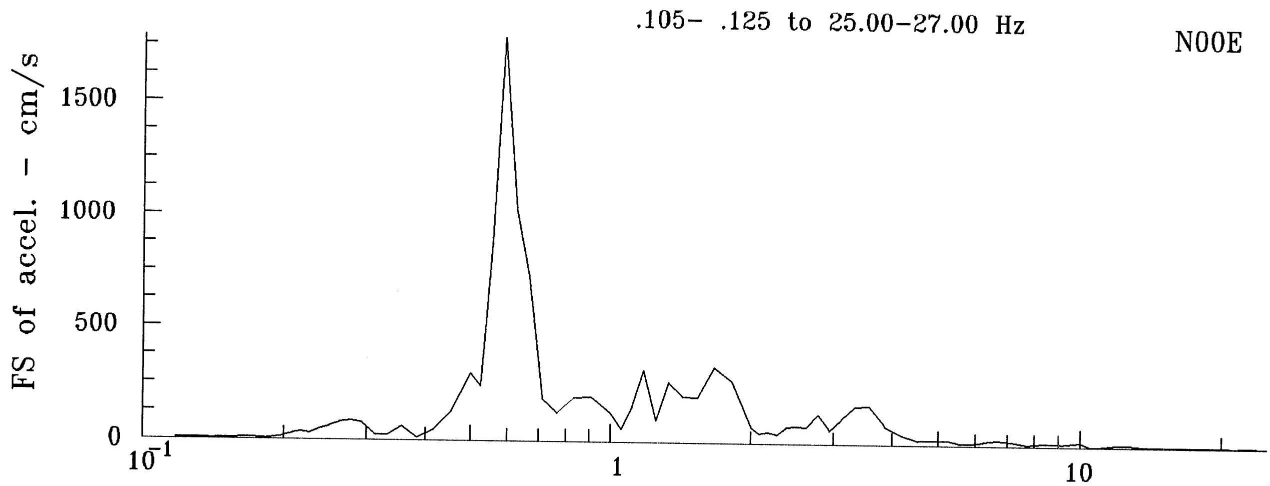


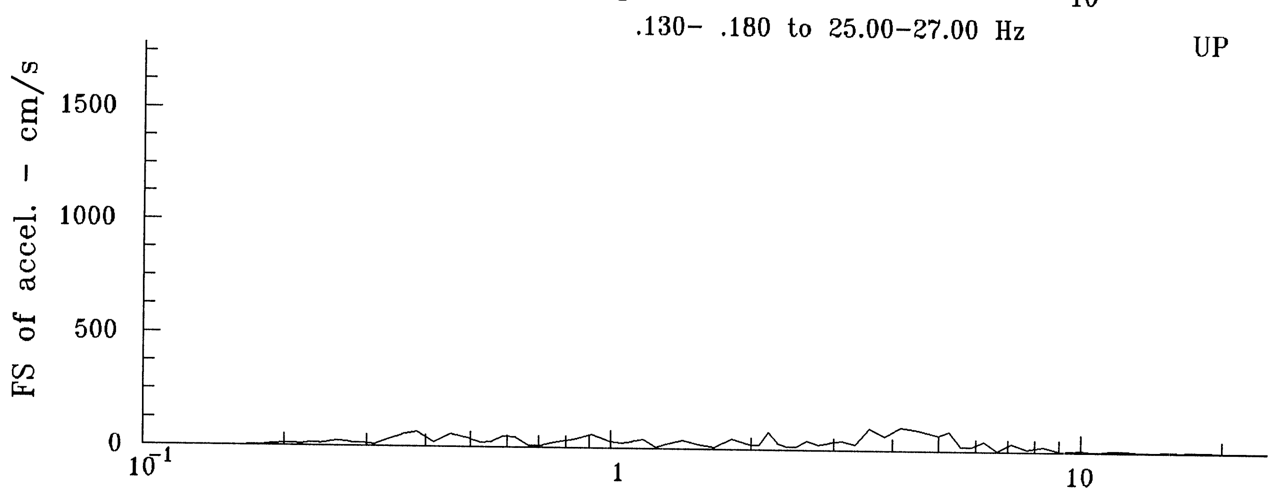
STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

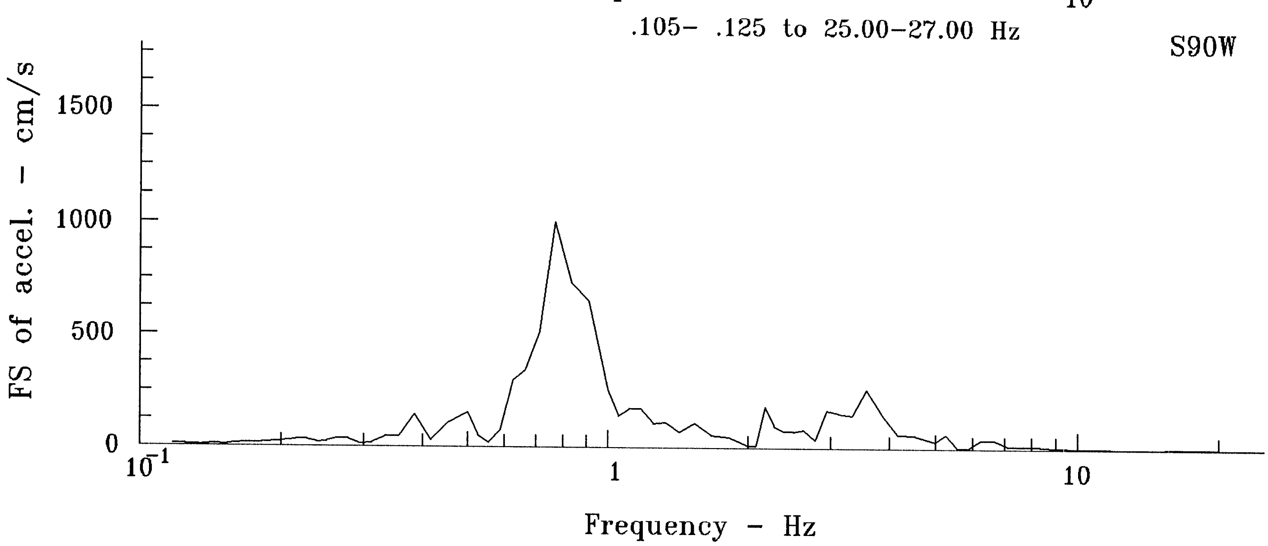
LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE JAN 17, 1994 -1230 GMT

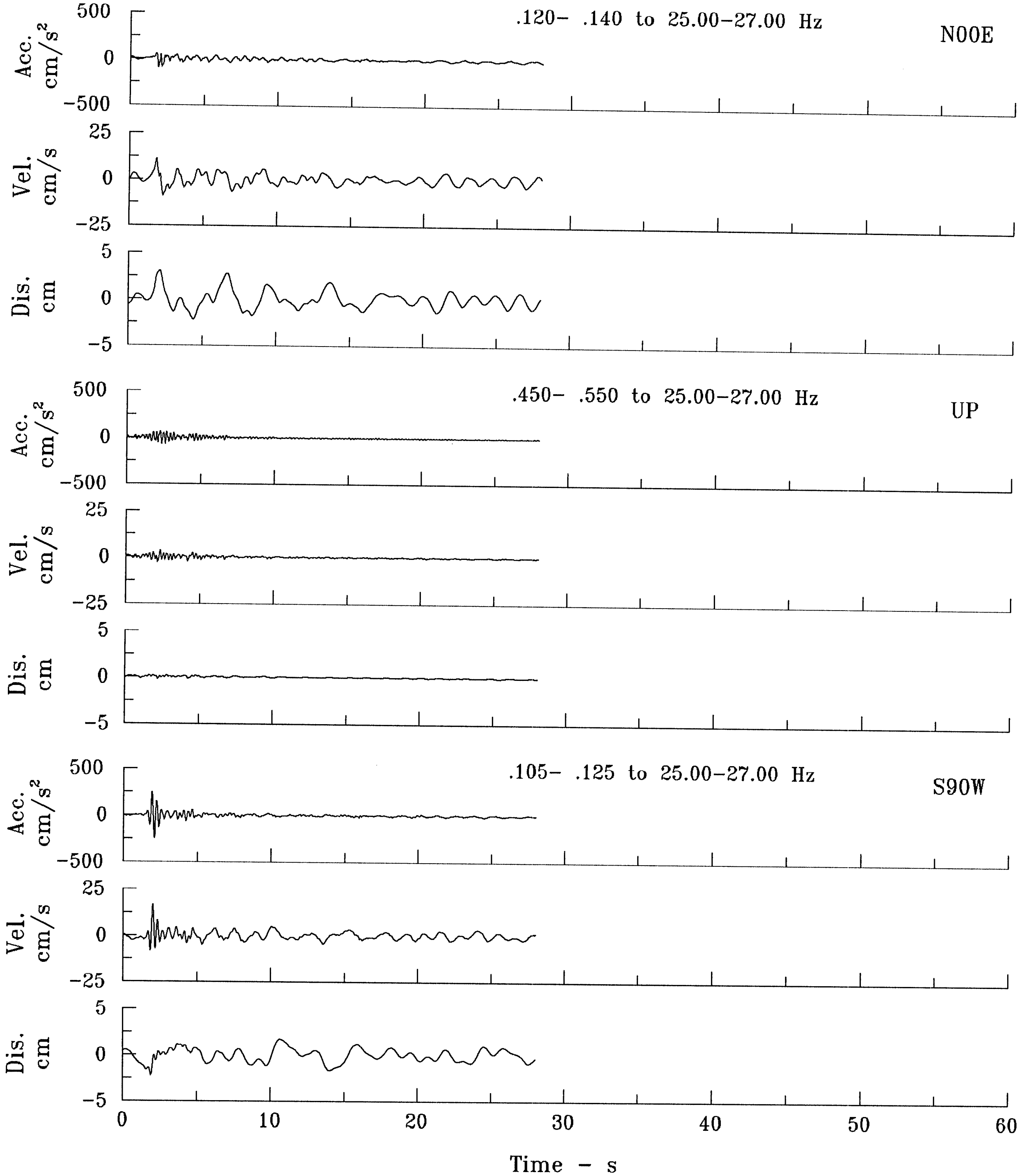
MAGNITUDE = 6.7 EPICENTRAL DISTANCE = 21.72 KM







STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491
LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)
NORTHRIDGE EARTHQUAKE (aft. -1) ?????? 1994 -???? GMT
MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

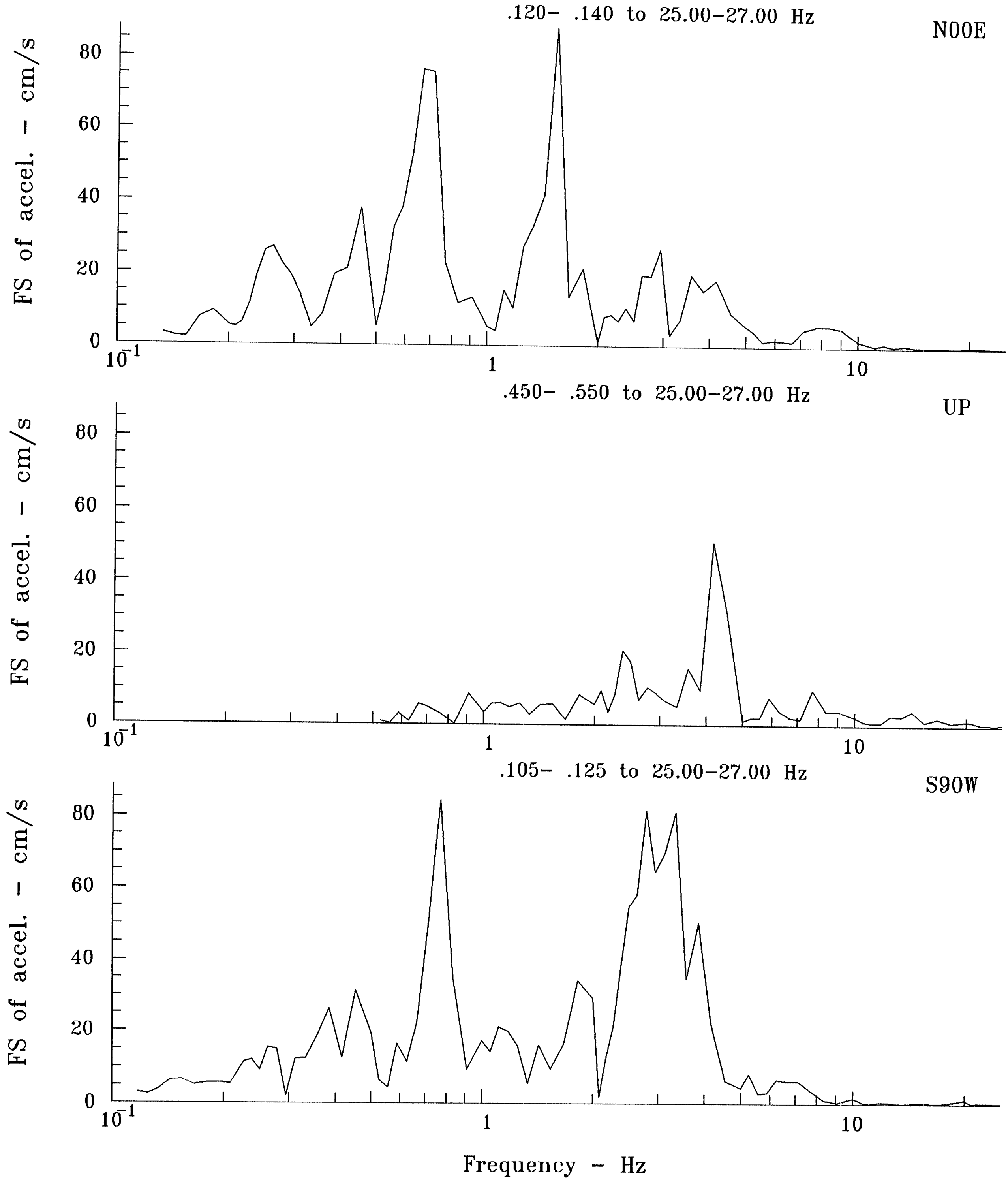


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -1) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

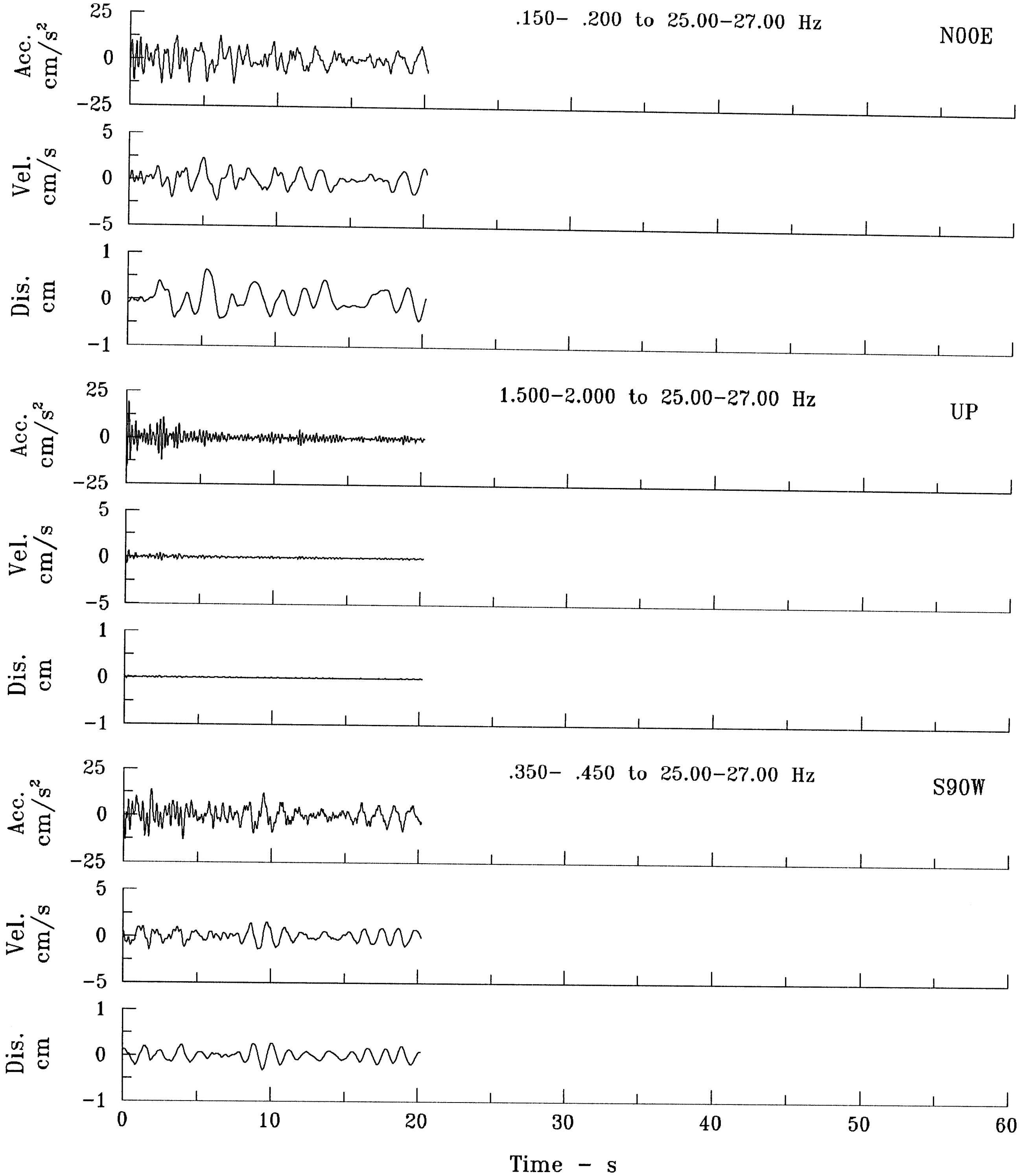


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -4) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

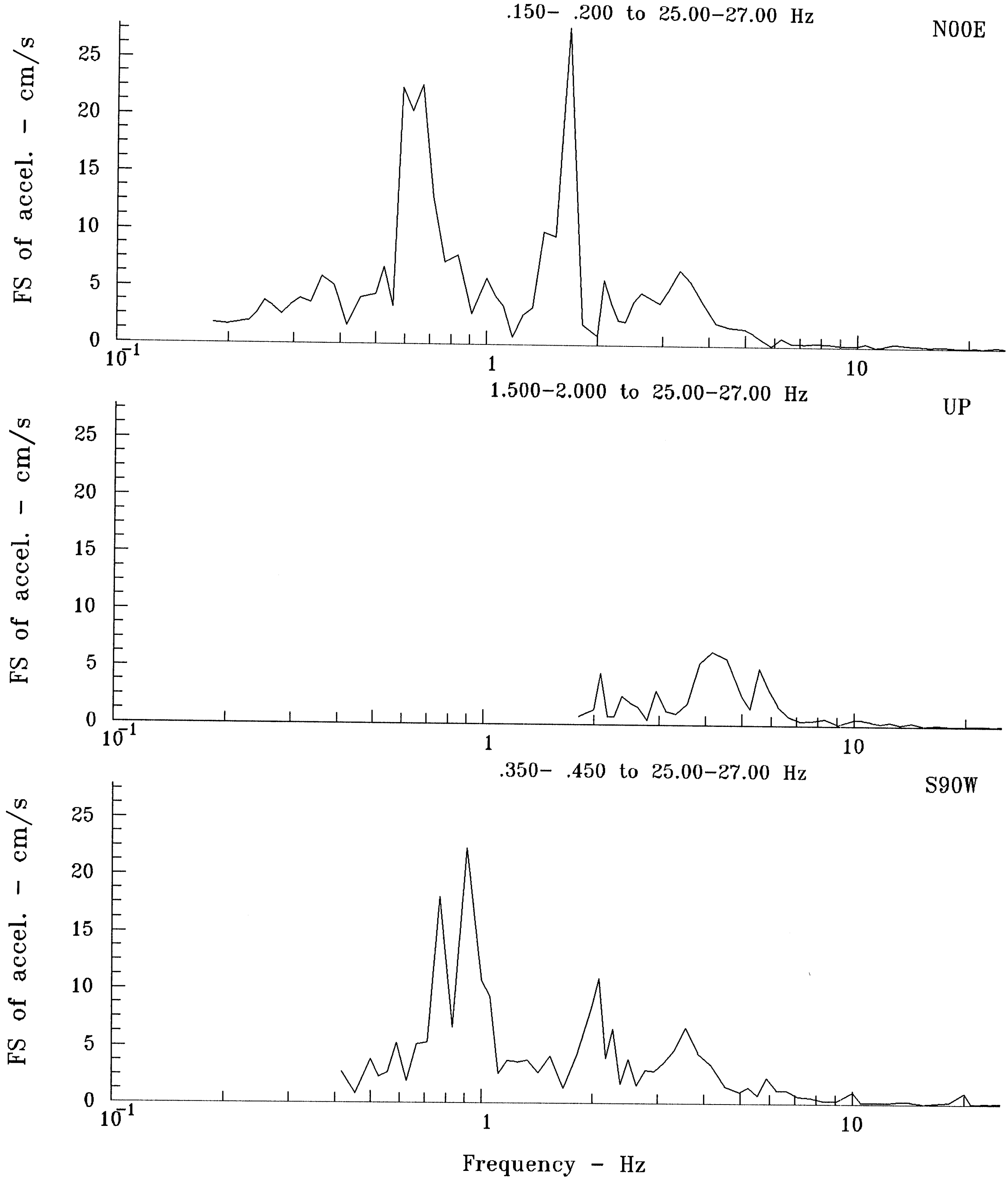


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -4) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

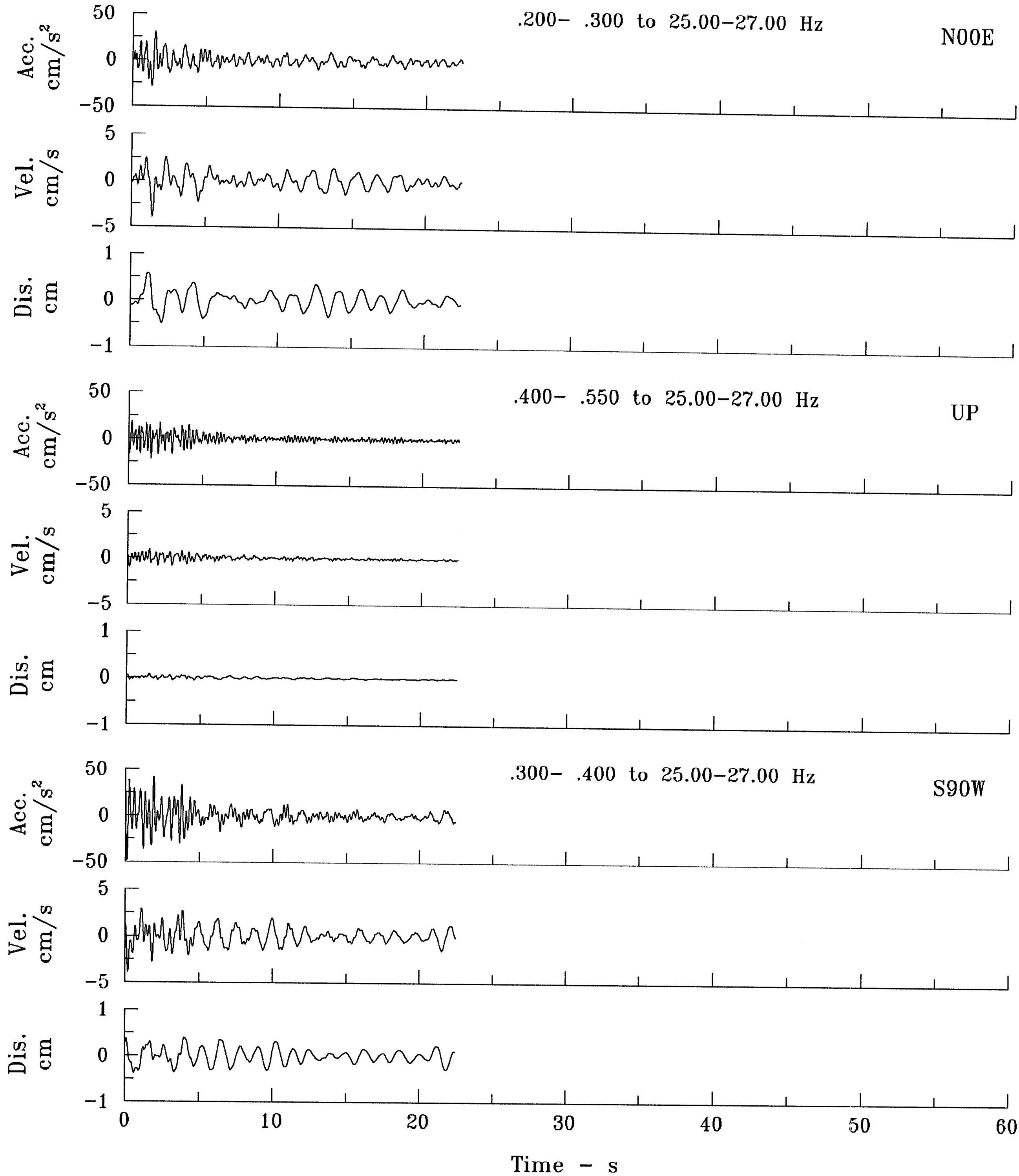


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -8) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

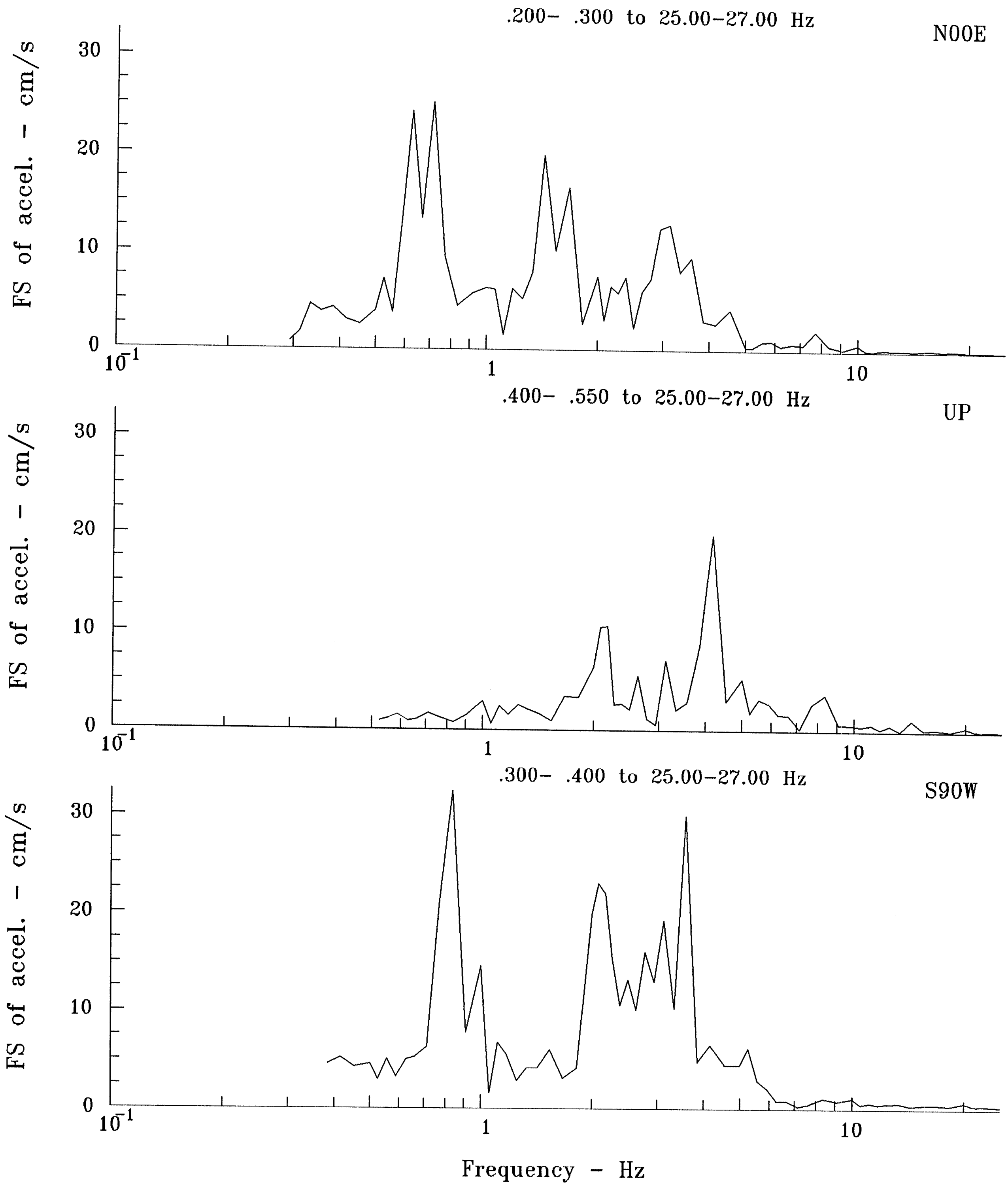


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -8) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

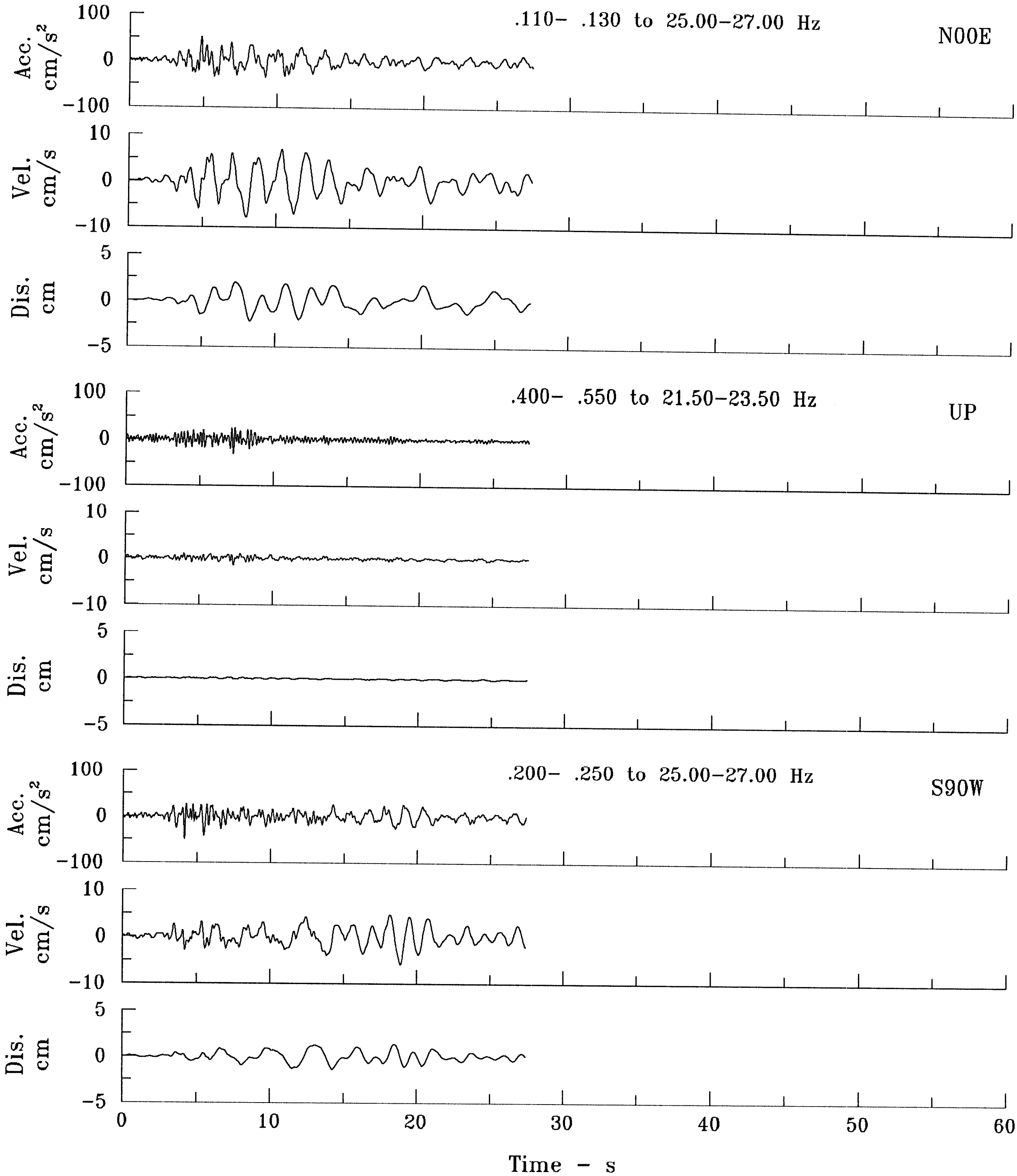


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -9) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

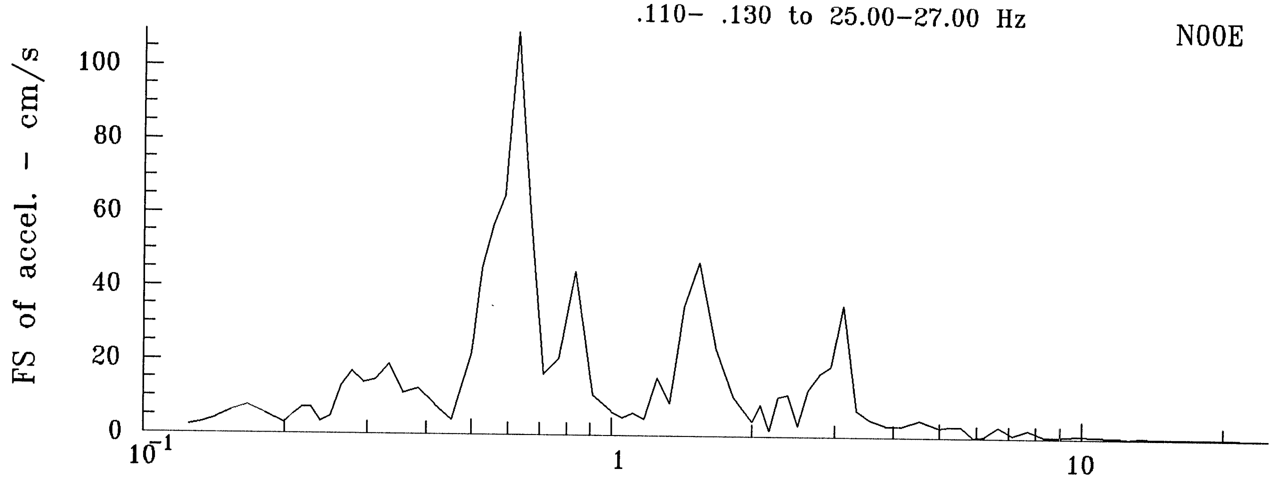


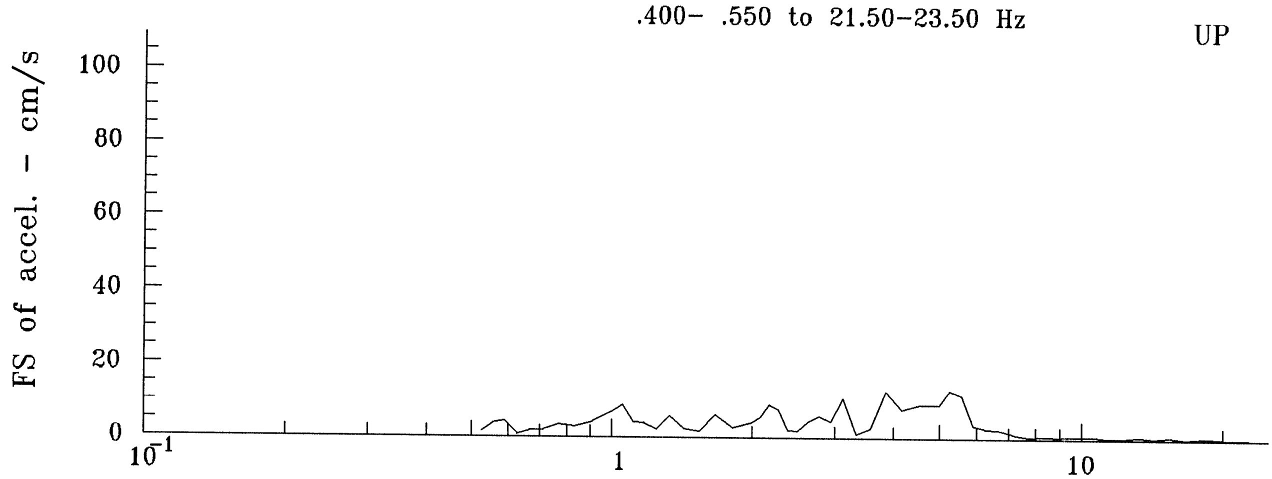
STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

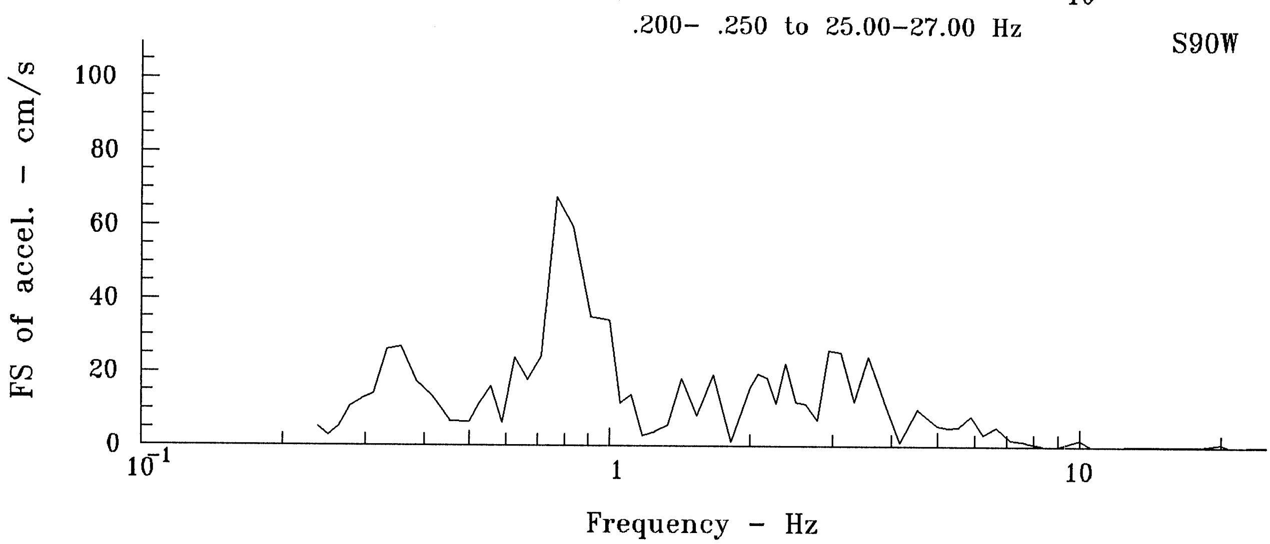
LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -9) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM





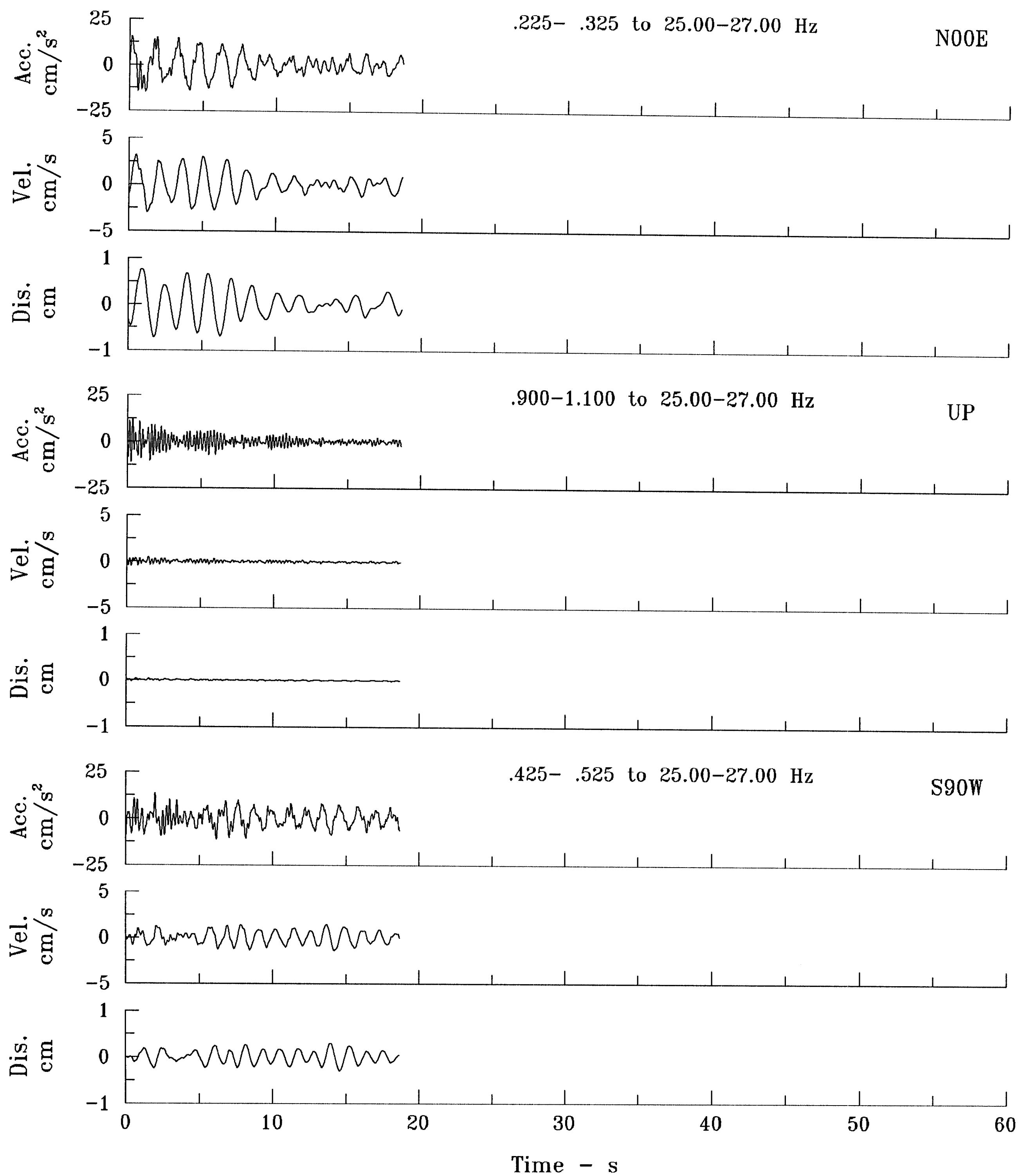


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -10) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

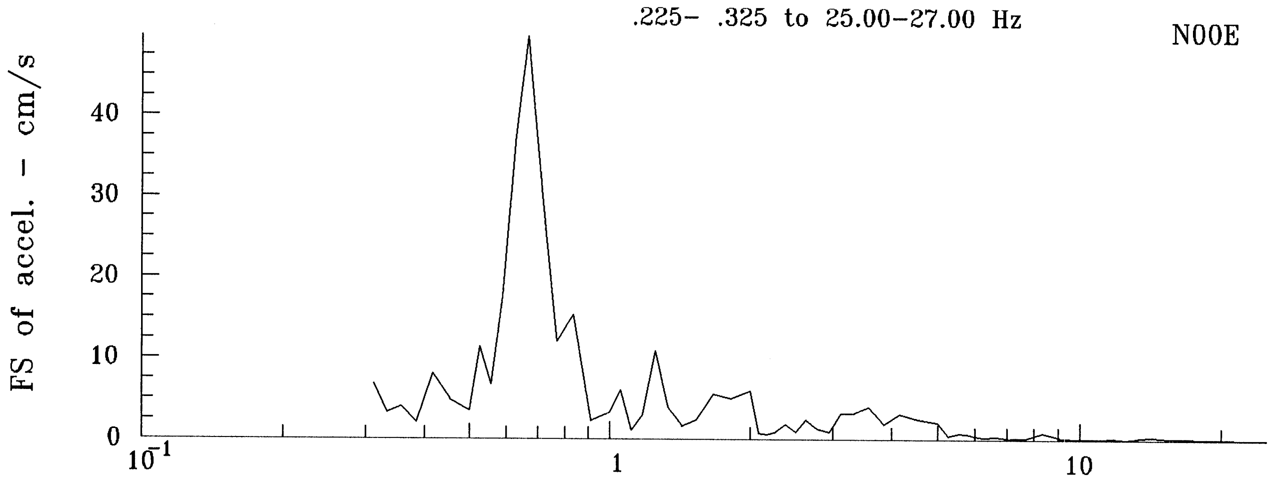


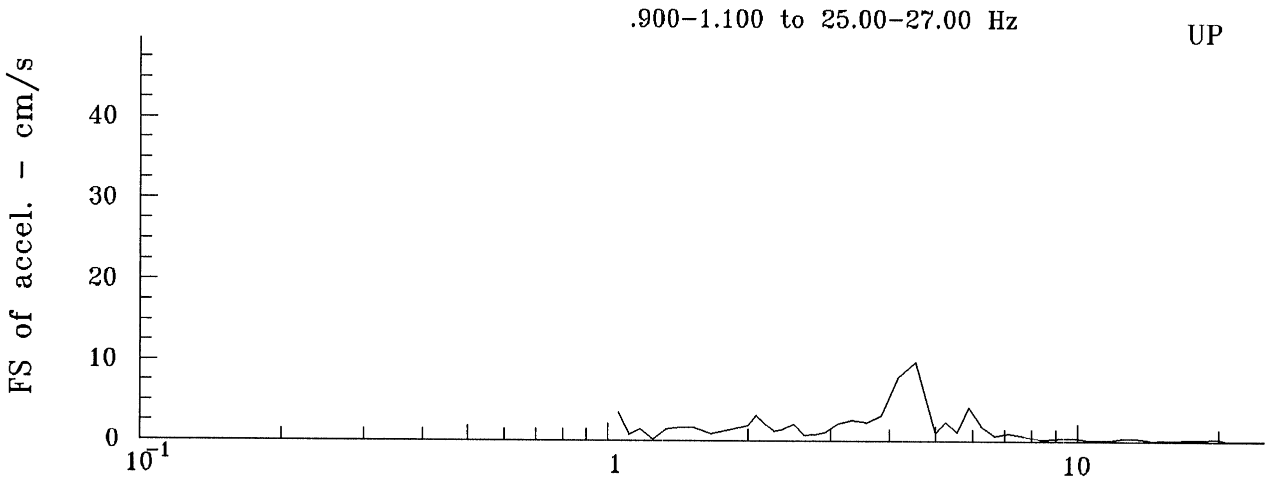
STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

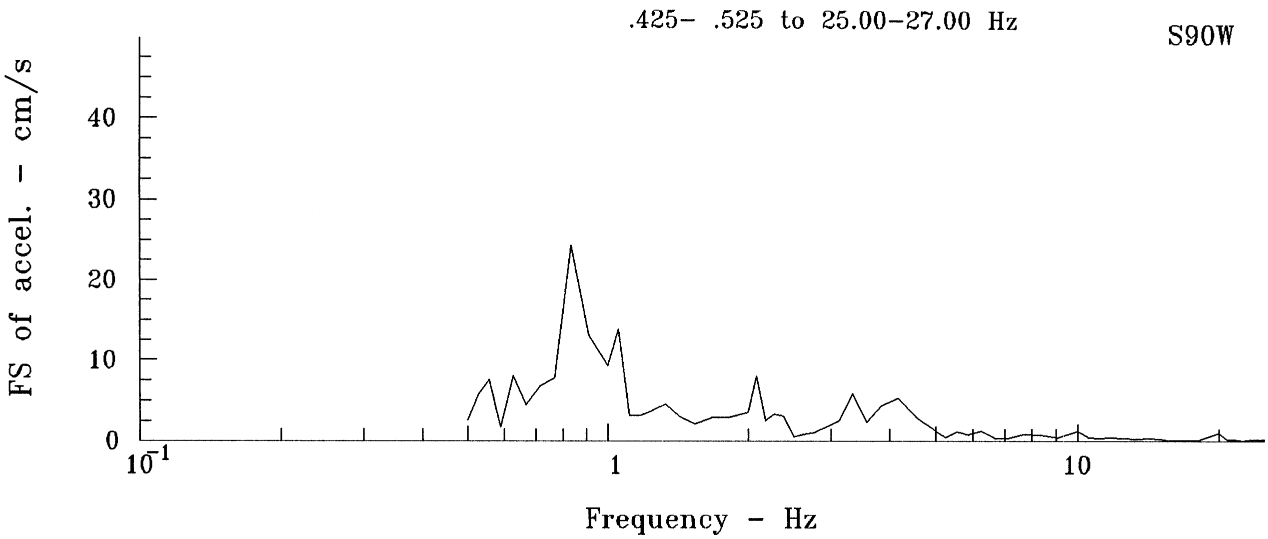
LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -10) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM





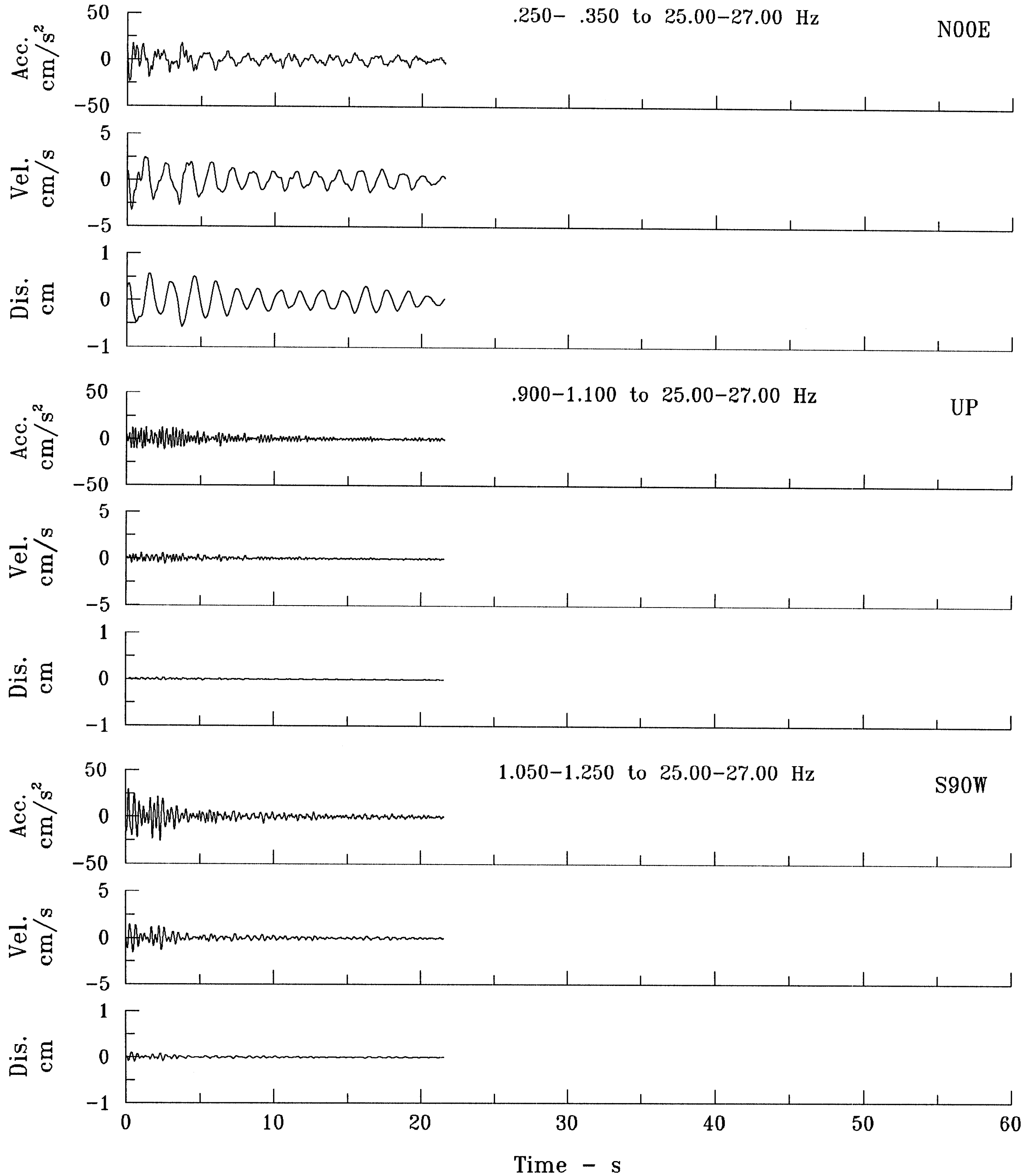


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -13) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

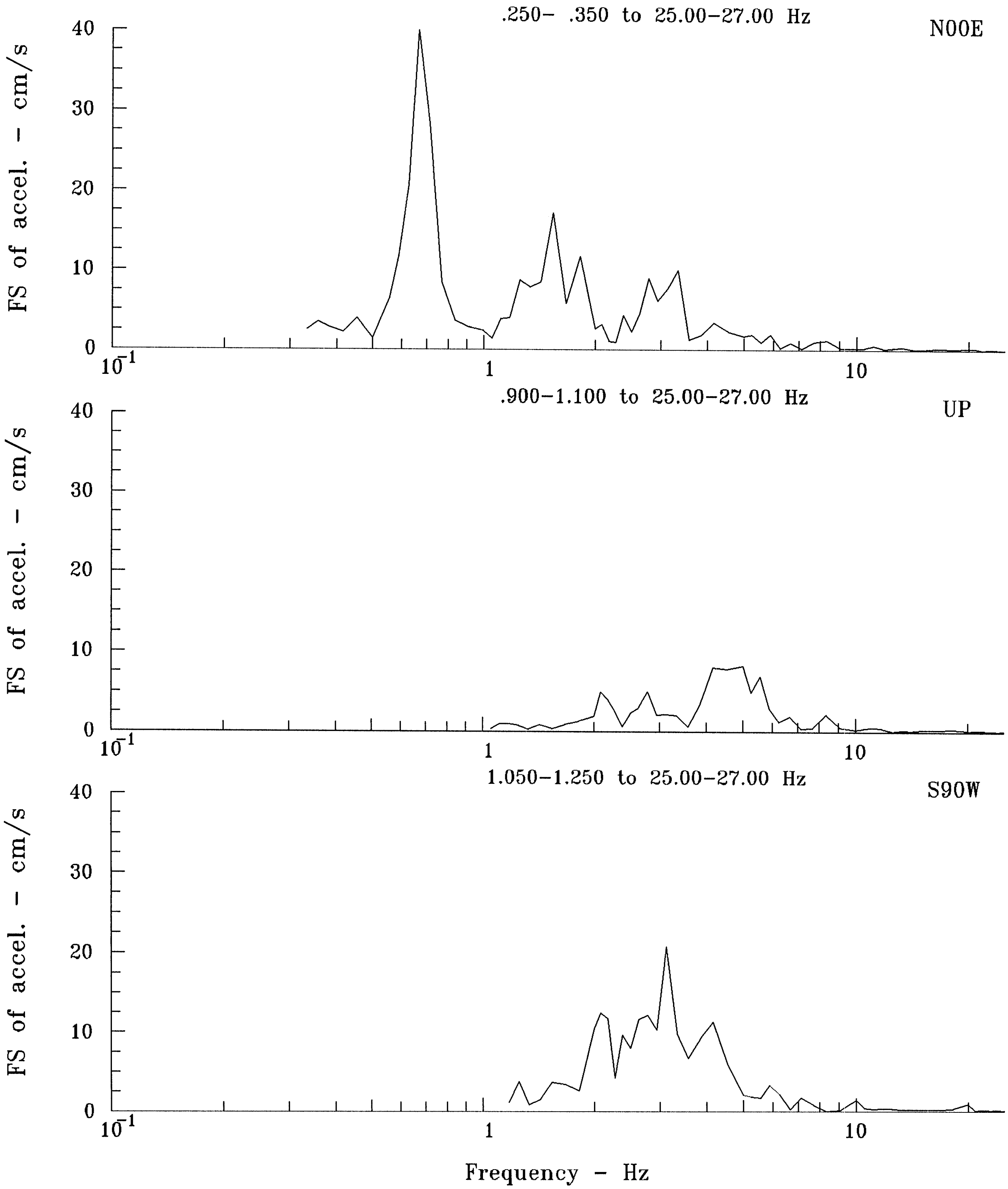


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -13) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

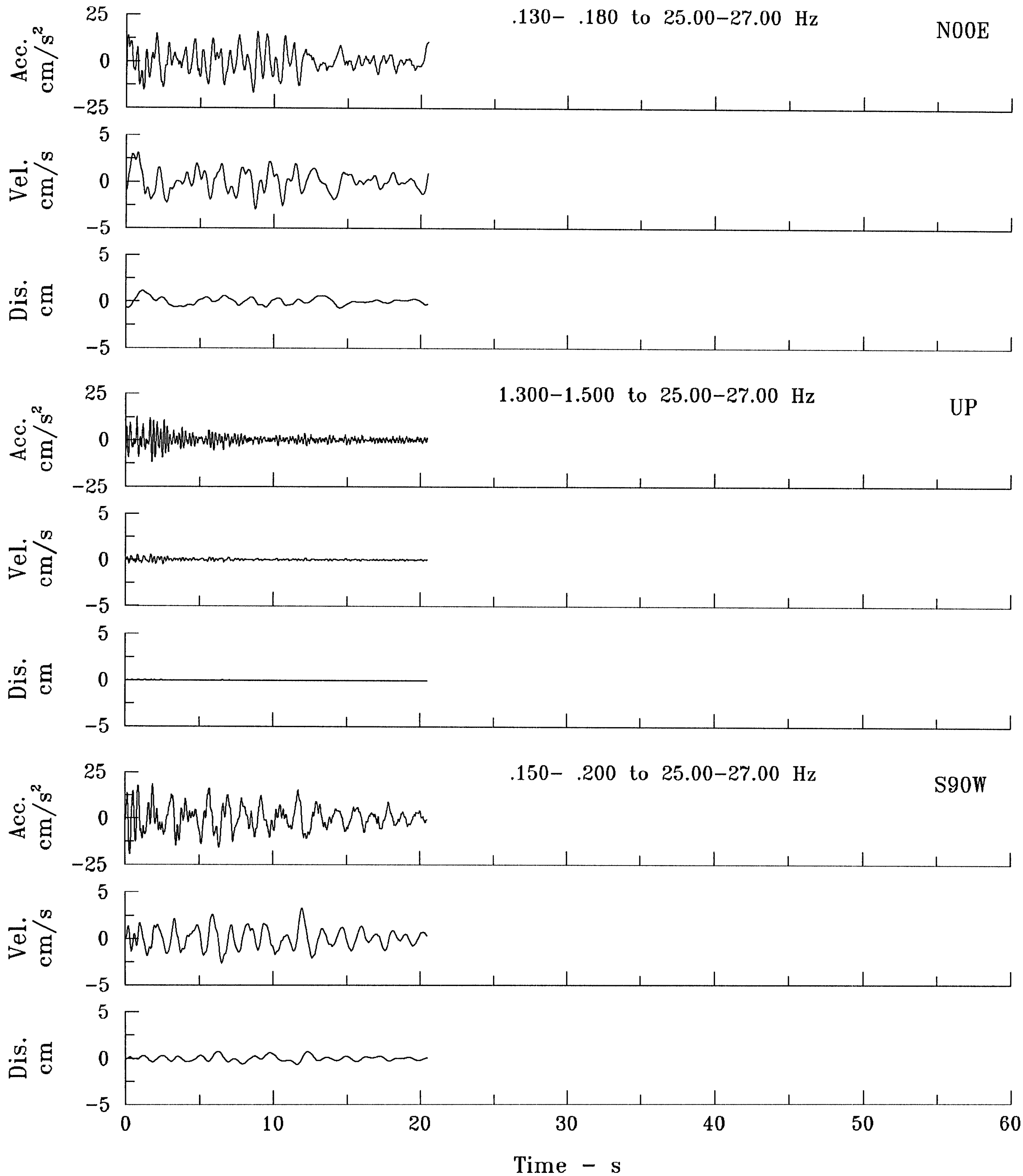


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -17) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM

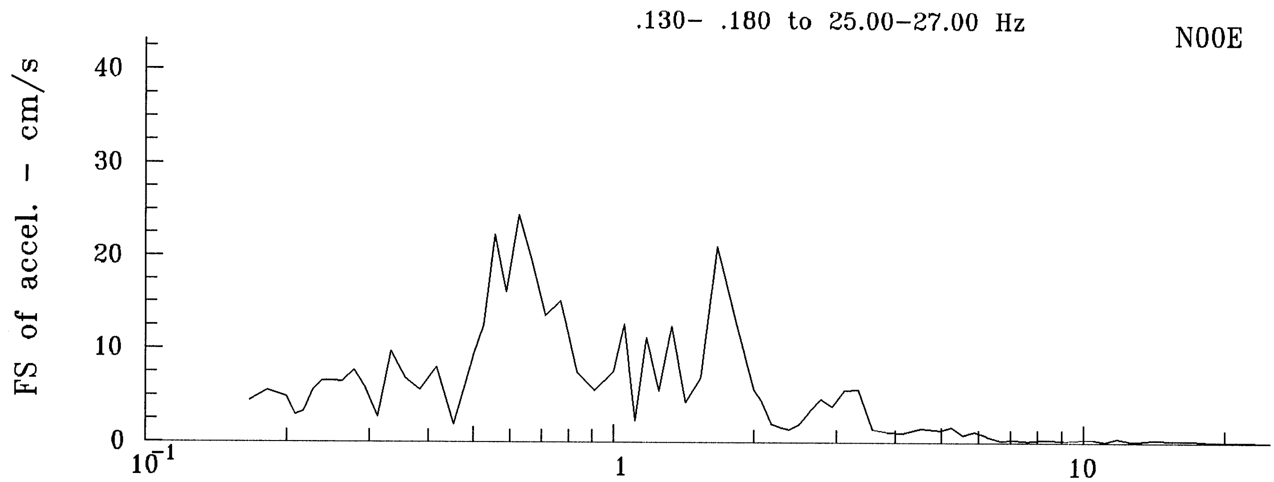


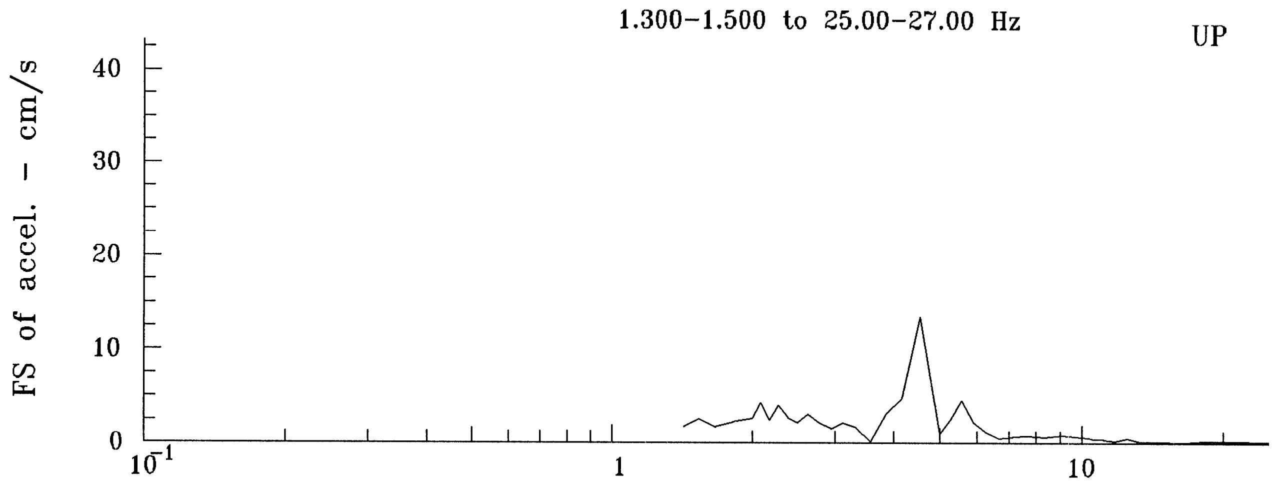
STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

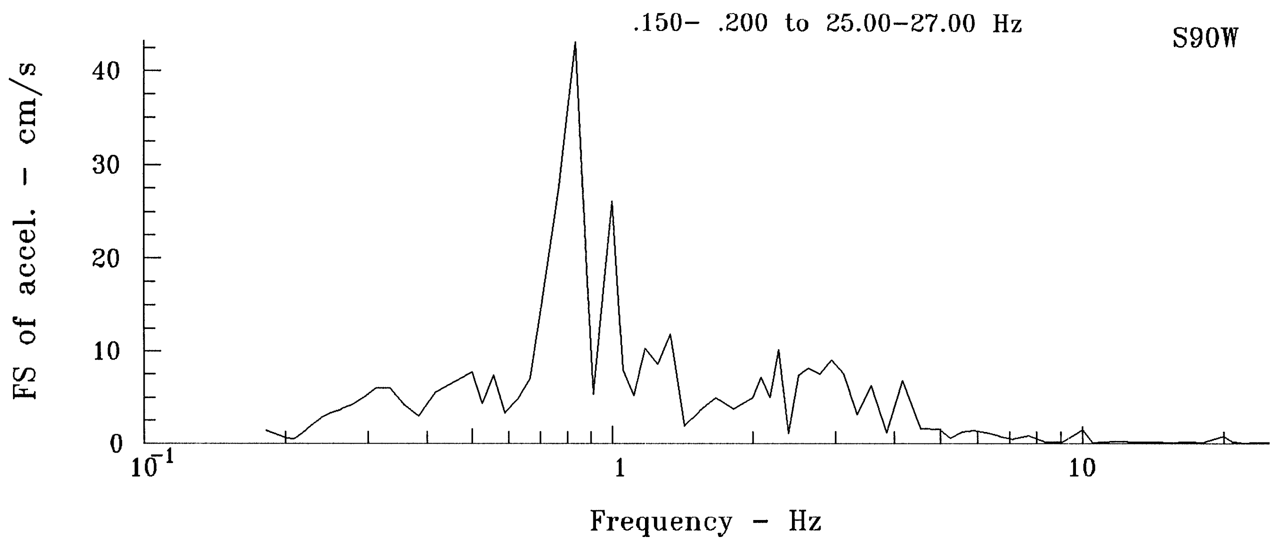
LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -17) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM





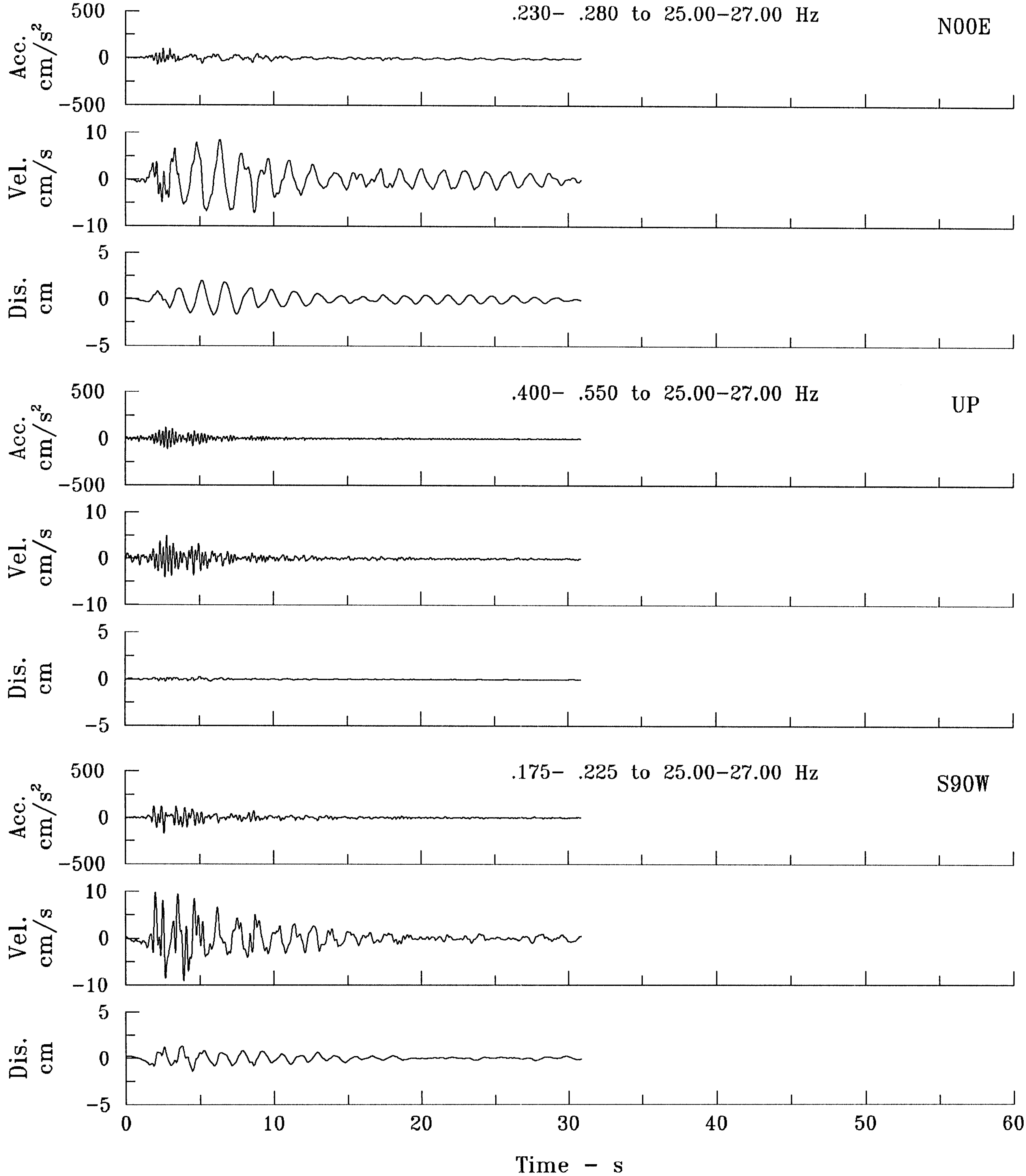


STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -19) ?????? 1994 -???? GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM



STATION USGS 5457 34.072 N, 118.375 W SMA-1 5491

LOS ANGELES, 8436 WEST 3rd ST., Roof (10th level)

NORTHRIDGE EARTHQUAKE (aft. -19) WXYZ00, 1994 -0000 GMT

MAGNITUDE = .0 EPICENTRAL DISTANCE = 27.36 KM